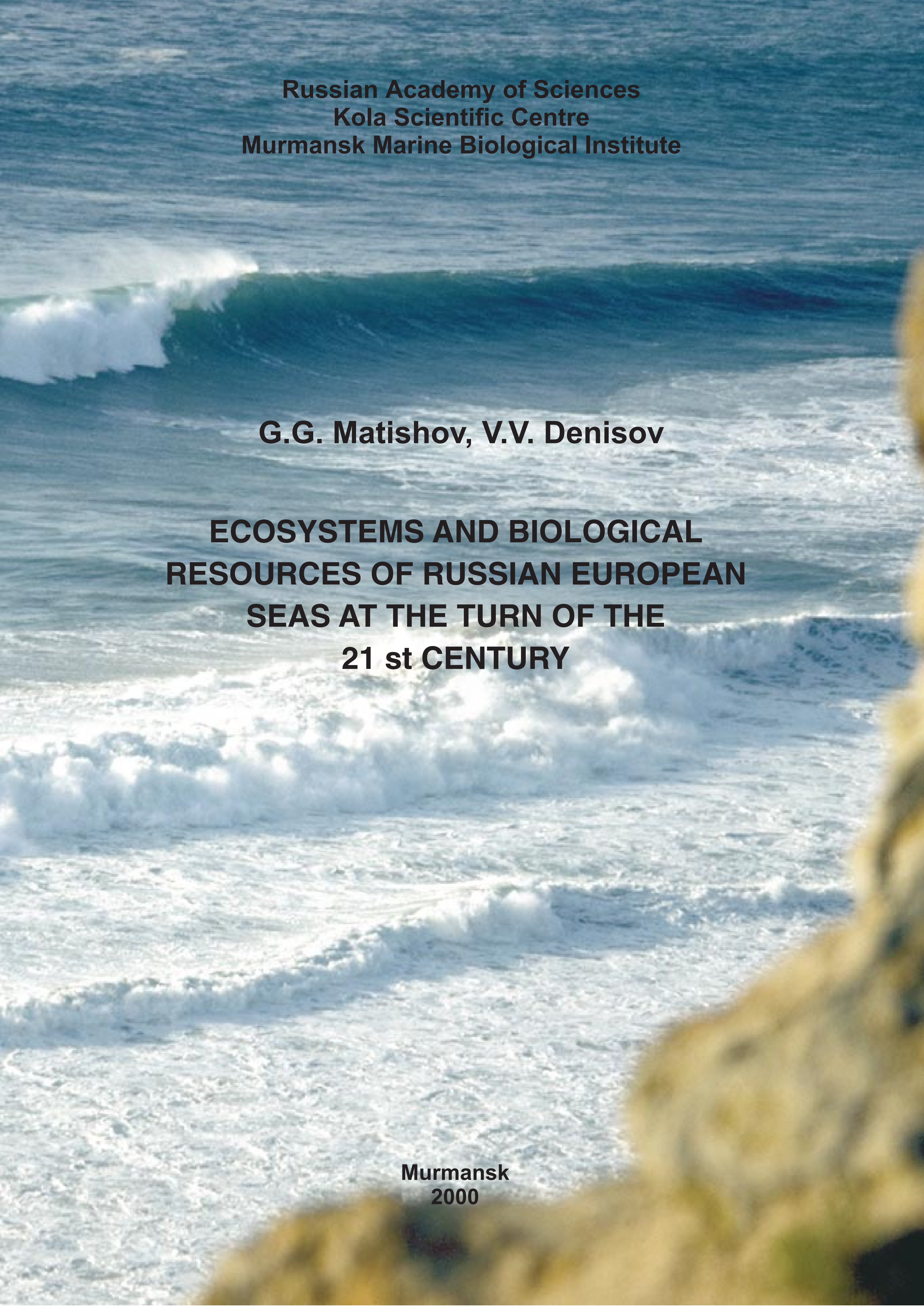

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ECOSYSTEMS AND BIOLOGICAL RESOURCES OF RUSSIAN EUROPEAN SEAS AT THE TURN OF THE 21 st CENTURY

Murmansk
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Contents

INTRODUCTION

Statehood of Russia and its economic development over last centuries have been closely connected to resources utilization of such water reservoirs in the European part of Russia as the Barents Sea, the White Sea, the Azov Sea, the Baltic Sea, the Caspian Sea and the Black Sea (**Fig.** 1). However, we sometimes fail to realize to what extent our lives are influenced by global processes going on in nature and how much we depend on abundance of the World Ocean.

Demand for fish and sea products is increasing every day, because they establish basis of wholesome nutrition, ecologically pure pharmaceutics and a number of new technologies. Annual yield of sea products amounts to over 110 mln tons and aquaculture products constitute nearly quarter of it. The share of Russian fishery is 4.5 mln tons per year, which is far from being maximum sustainable catch of the Russian waters.

At the same time we witness exhaustion of stocks of traditional fishery and hunting objects such as fishes, whales, birds, seals. Now we face problems of overexploitation, disruption of natural reproduction and even threat of extinction of some species.

In recent years politicians, businessmen and society have become increasingly conscious of complex problems of marine ecosystems and marine resources preservation. In Russia and abroad this issue has often been discussed at scientific conferences and meetings of different levels and found its reflection in numerous publications.

Nevertheless, the need for more detailed studies, especially sea surveys, and the use of their results for development of new methods becomes really important. In the present situation of crisis, this issue comes fore as particularly acute problems of continuity of marine studies on the sufficient level and preventing experts from switching to other activities arise. It is noteworthy that a series of legislative efforts has been carried out recently in order to regulate bioresources exploitation. Their guidelines can be found in two strategic documents – the President of the Russian Federation decree N 440 from 01.04.96 «On the concept of the Russian Federation transition to the sustainable model of development» and the Russian Federation Government decision N 669 from 01.06.96 «On the measures necessary for the implementation of «The Biodiversity Convention». In accordance with the above mentioned documents all departments should cooperate with representatives of the executive power and the Academy of Science of the Russian Federation in order to elaborate agreed scheme of cooperation and meet international commitments of the Russian Federation. In addition, protection and sensible use of bioresources are regulated by Chapter 2 of the Russian Federation Shelf Law and the Russian Federation Government Decree N 1490 from 14.12.98 «On strengthening of state control over bioresources exploitation».

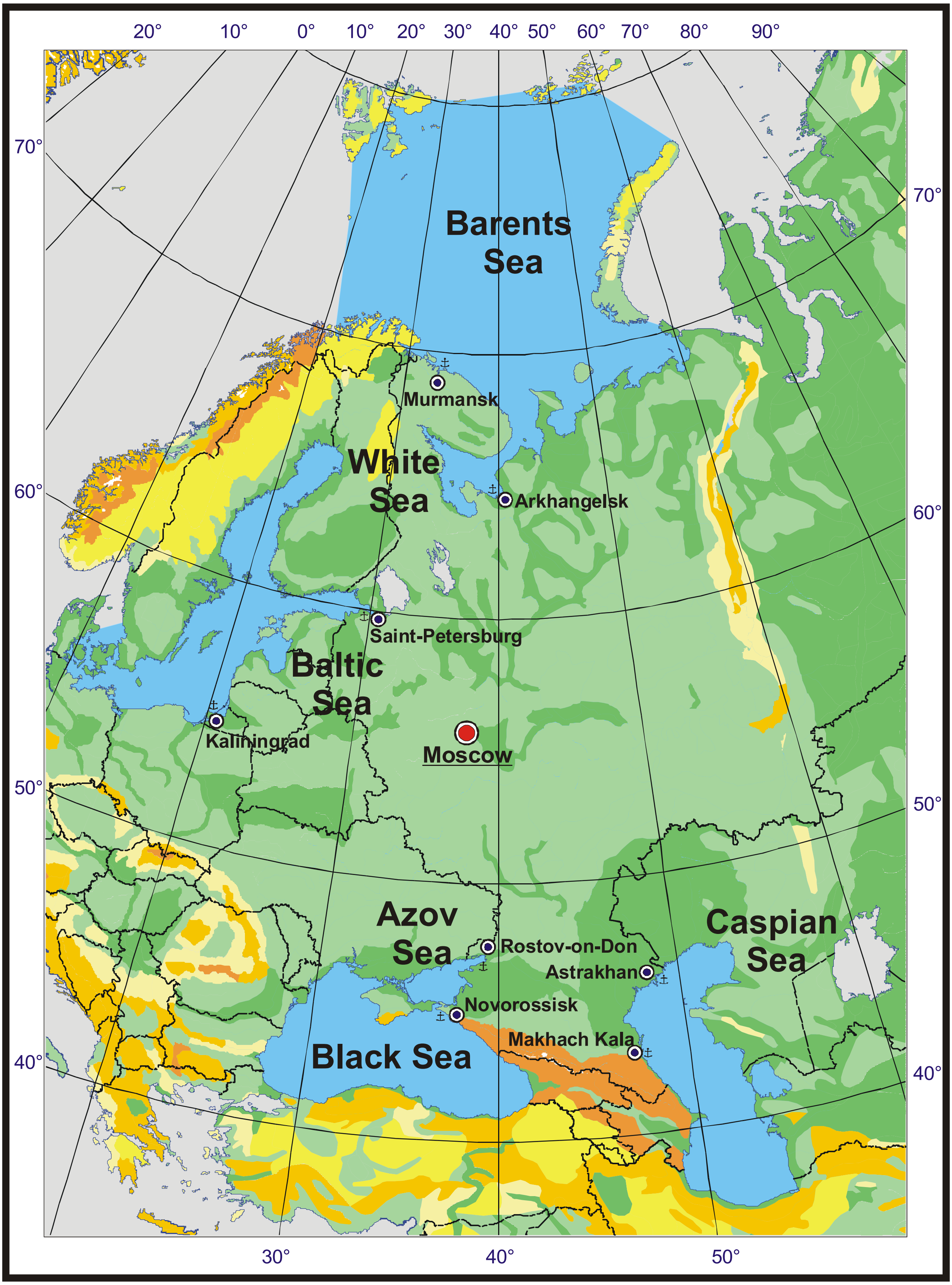


Fig. 1. European seas of Russia

The subject of this book is to summarize data, bring together different approaches to the development of marine biota and its environment at the turn of the century, to analyze reasons and biological consequences of ecological crisis of the seas in the European part of Russia, to discuss possible ways of stabilization of unfavorable trends in ecosystem dynamics and maintain their efficiency.

Another reason for creating this book was our growing concern over poor cooperation between academic science and applied sciences in attempt to develop scientific approach to aquaculture and marine biotechnology. While writing this book we used numerous materials and data gathered by different institutes and organizations listed below:

- *Murmansk Marine Biological Institute KSC RAS (MMBI)*
- *P.P. Shyrshov Institute of Oceanology, RAS (IO)*
- *Severtsev A.N. Institute of Problems of Ecology and Evolution (IPEE)*
- *Scientific Council on Hydrobiology and Ichthyology problems RAS*
- *Interdepartmental Ichthyologic Committee*
- *State Fishery Committee of the Russian Federation*
- *All-Russian Scientific-research Institute of Marine Fisheries and Oceanography (VNIRO)*
- *Polar Scientific-research Institute of Marine Fishery and Oceanography(PINRO)*
- *Caspian Fishery Scientific-research Institute*
- *Azov Fishery Scientific-research Institute*
- *JSC «Sevryba»*
- *«Murmansk Trawlers' Fleet», Ltd.*
- *State Environmental Protection Committee of the Russian Federation*
- *Scientific-research Institute of Nature Protection and Reserves*

Murmansk Marine Biological Institute KSC RAS (MMBI) has been engaged in complex sea studies in the West Arctic regions since 1935 (**Fig.** 2–4). The Azov Sea has been recently included into the scope of the Institute studies. MMBI includes some branches of applied sciences alongside profound scientific research in oceanology and biology. These branches are development and exploitation of non-traditional fishery objects, evaluation of shelf gas and oil extraction influence on marine ecosystems, and modeling of chemical and radioactive pollutants distribution in the seas. The studies resulted in the publication of over 50 monographs and collections of articles (see Appendices).

Materials collected by the authors for the report at the meeting of RAS Presidium (February 1999) formed the basis for this book. The authors express gratitude to RAS Academicians M.E. Vinogradov and D.S. Pavlov, RAS correspondent member Y.A. Zhdanov, director of *VNIRO* Dr. B.N. Kotenev for valuable advice and helpful criticism; Director General of JSC *«Sevryba»* G.V. Tishkov, Director of *PINRO* Dr. F.M. Troyanovsky, Dr. V.N.Shleinick, managers of *«Murmanrybvod»* A.V. Zelentsov, B.F. Pryshchepa for data and participation in discussions on the seas of the Northern regions; Director of *Azov Fishery scientific-research institute* Dr. E.V. Makarov, Deputy Director of *Azov Fishery Scientific-research Institute* Dr. S.P. Volovik, Department Manager of *Hydrochemical Institute* Dr. Y.A. Fedorov, Head of the Chair of *Rostov State University* Dr. Y.P. Chrustalev, Deputy Director of *«Azrybvod»* office V.E. Yegorov – for materials on the seas of the South.

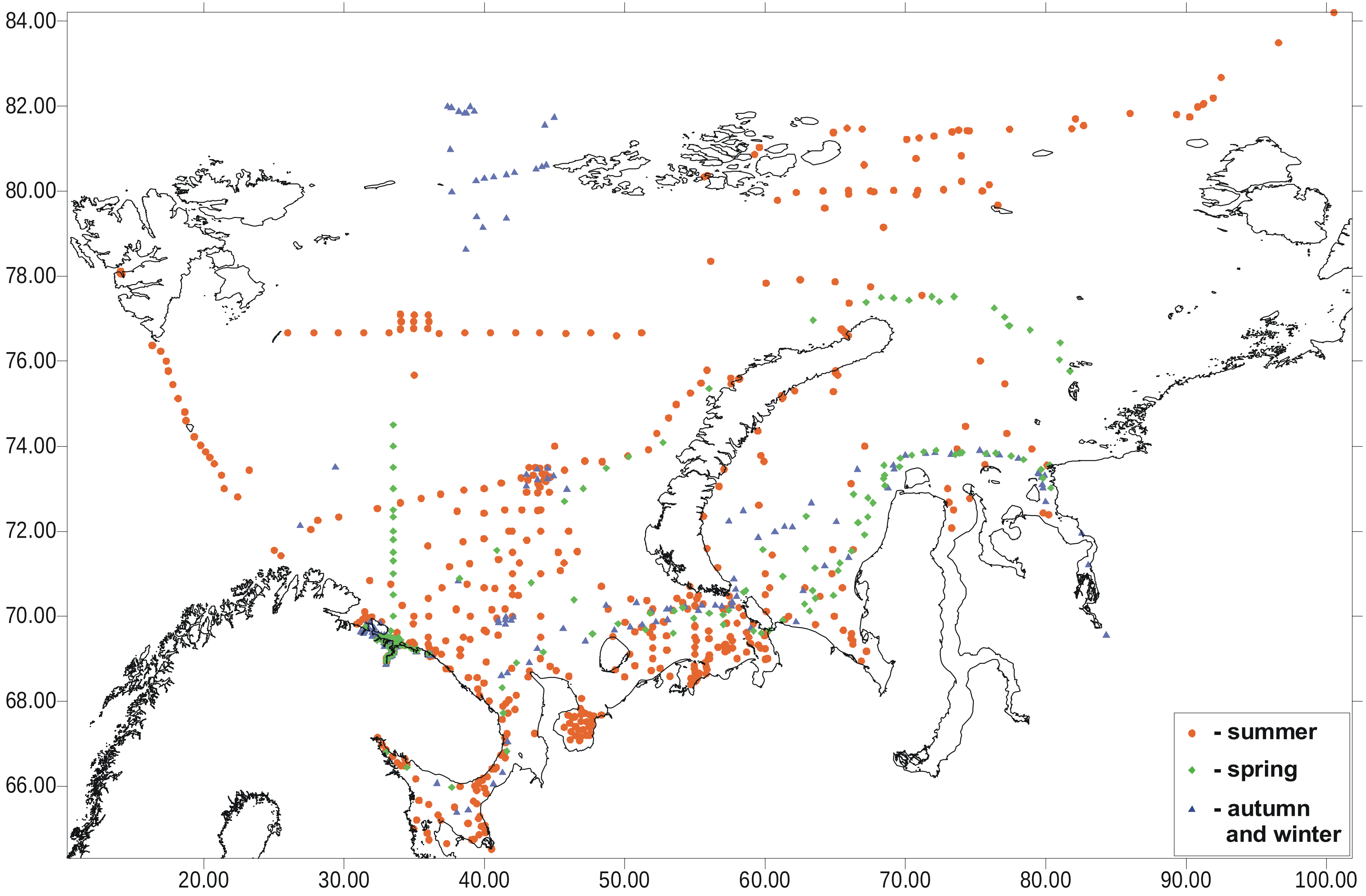


Fig. 2. Scheme of planktonic stations carried out during MMBI cruises from 1991 till 1998

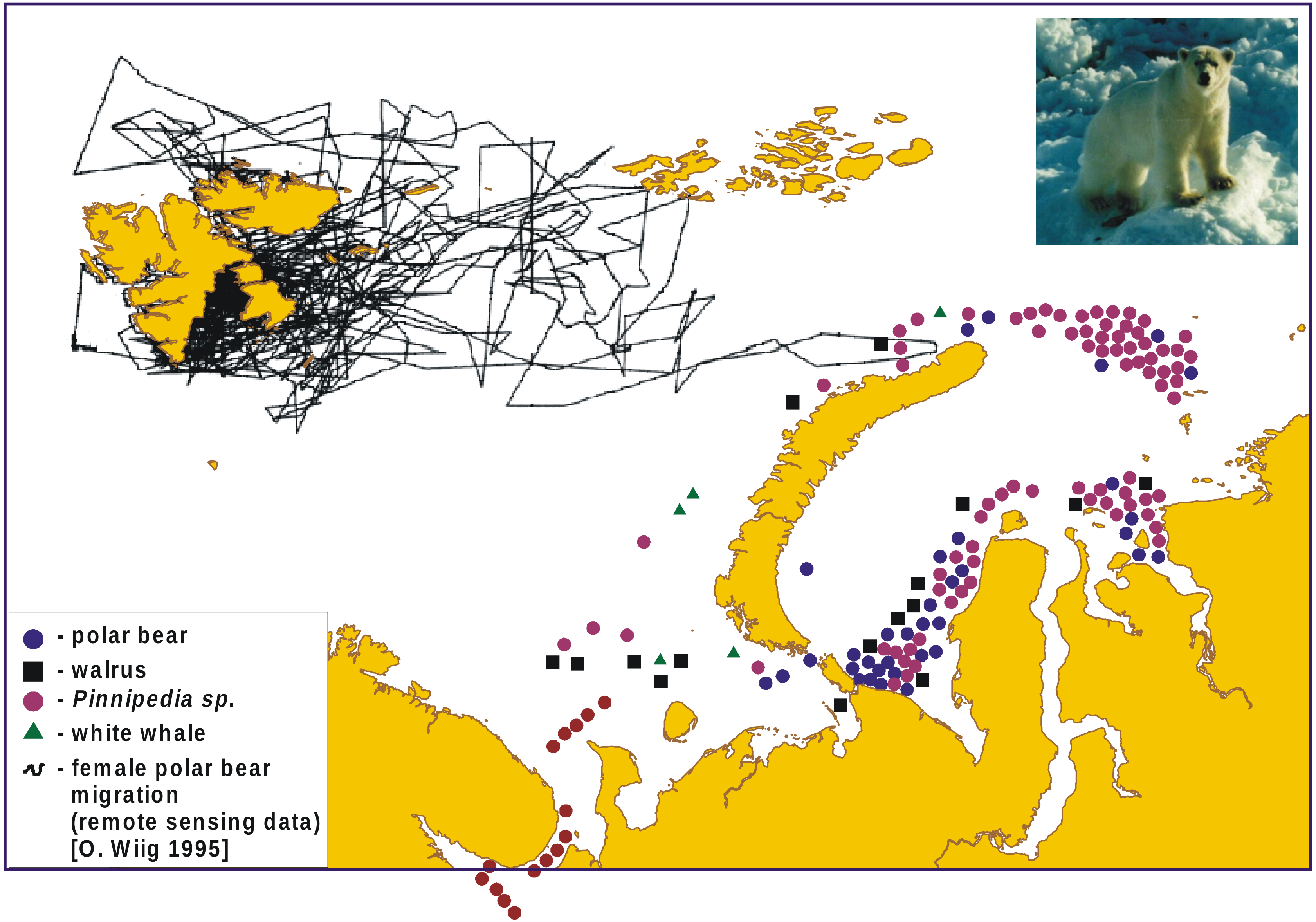


*Fig. 3. Coupling of the satellite sensing (*NPI, Norway) *and simultaneous observations from ice-breakers* (MMBI, Russia) *of the polar bear habitat in the north of the Barents and the Kara seas*

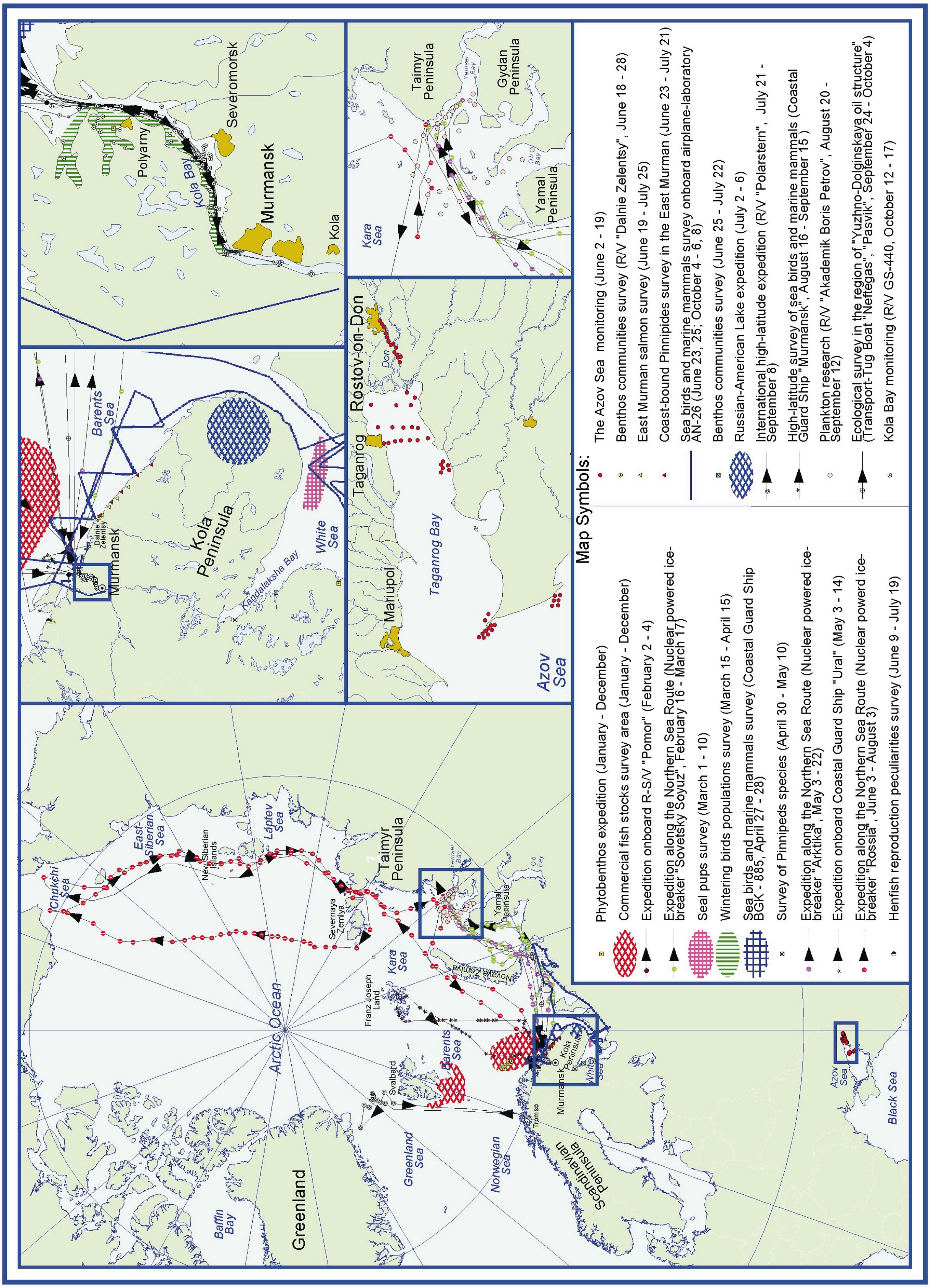


Fig. 4. Map of MMBI expeditions in 1998

We shall thank for discussion and help at the draft copy stage our colleagues Prof. S.F.Timofeev, Dr. I.A. Shparkovsky, Dr. Y.V. Krasnov, Dr. O.V. Karamushko, Dr. V.L. Mishin, Dr. A.A. Kondakov, Dr. V.S. Petrov, Dr. G.V.Stepachno, Dr. D.G. Matishov, Dr. S.L. Dzhenyuk, Dr. A.D. Tchynarina. Design and graphics are accomplished by MMBI personnel V.A. Golubev, Dr. E.E.Kirillova, A.V. Kusnetsov, N.A. Kukina, D.V. Moiseev, L.V. Tarakanova.

Completion of this book would have been impossible without long-range cooperation and financial support of MMBI scientific and scientific-commercial surveys from RAS Vice President N.P. Laverov, secretary academicians of *OOB* and *OOFAG* of RAS N.G. Chruschov and Y.A. Israel, *State Fishery Committee of the Russian Federation* experts (V.F. Korelsky, A.V. Rodin, V.A. Izmailov, S.E. Dyagilev), *RAO «Gasprom»* (B.A. Nikitin, V.S. Vovk, A.Y. Mandel), *Commander in Chief of the Northern Fleet* Vice Admiral V.A. Popov, Counter Admiral A.P. Makorta, Admiral I.I. Naletov (*Federal Service of Frontier Navy*), *Federal Frontier Guards* – General Mayor A.V. Koretsky, Counter Admiral V.K. Logvinenko and the authors give thanks to all of them.

Funding was provided through the department of Commerce by the National Oceanic and Atmospheric Administration’s (NOAA) Environmental Services and Data Management (ESDIM) Program managed by the National Environmental Satellite Data and Information Service (NESDIS), Office of Environmental Services (EIS). The Murmansk Marine Biological Institute wishes to acknowledge the NOAA National Marine Fisheries Service’s (NMFS) Office of Science and Technology and Dr. John T. Everett , Chief Division of Research, Analysis &Coordination for editing the translated monograph and facilitating its publication.

NATURAL FLUCTUATIONS OF ECOSYSTEMS

Marine biology and fishery biology owe much to studies of Russian scientific and fishery institutes. The monograph *Studies of fishery in Russia* in 9 volumes published in Russia back in 1860–1875 is a good example of it. However, the old paradox holds good: the more we learn the less we understand the nature of latent changes in marine ecosystems, including those caused by human activities (**Fig.** 5).

Balanced use of marine bioresources is impossible to imagine without profound understanding of the nature of phenomena and processes developing in marine ecosystems which are complex structures with multiple levels in the thick layers of water including both benthic and pelagic zone. Marine ecosystems extend horizontally from shallow waters of the coastline zone to the bed of the continent through shelf and further include bottom ridges and abyssal areas (Lisytsyn and Vinogradov 1982, Matishov and Pavlova 1990).

Colossal energy and matter fluxes from plankton and benthos to birds, whales, polar bears, walruses via ichthyofauna take place inside marine ecosystems owing to trophic chains and migrations, both active and passive, for hundreds and thousands miles. One should bear in mind, that peak activity of biota is determined by hydrological fronts causing thermo cline, upwelling zones, ice-field edges, estuaries of principal rivers. Hydrothermal areas, open water areas in the ice-fields, underwater ridges are oases of life. All these contribute to a complex structure of ecosystem where mankind plays a role by exploiting valuable commercial species. And to crown it all, ecosystems are exposed to complex natural and anthropogenic influences.

Marine ecosystems develop against the natural background of climatic fluctuations and lifecycles of biota. It is known, that there are big fluctuations in abundance of certain year-classes of some hydrobionts which are closely connected with the natural fluctuations of natural mortality rate of non-commercial marine species.

Bioproductivity of reservoirs and fishery efficiency are influenced greatly by climatic changes on the global scale characterized by recurrent pattern (**Fig.** 6). Marine ecosystems of the shelves of the Azov, Barents, White and some other seas reflect complex geological history related to intermittent glacial and periglacial periods and sea level fluctuations (**Fig.** 7). That is why marine biota is adapted to large scale climatic fluctuations (Matishov and Pavlova 1990).

Sharp climatic anomalies produce specific impact on marine ecosystems cycle. These periods are responsible for breakdowns of trophic and other interrelations within ecosystems. Experts suppose that we are facing the change of the climatic epoch when the prevailing type of the air masses circulation is being modulated causing «cold winters» in the Western Africa and Europe. The latest data show the increasing variation of temperature range in the Northern Hemisphere, which indicates that the climatic system is unstable on the whole.

PHENOMENA	SEA
Long-term fluctuations of climate	BARENTS BALTIC WHITE BLACK AZOV CASPIAN
Anomalous excess of ultraviolet radiation dozes (through "holes" in the ozone layer)	BARENTS
Cyclic advection of warm Atlantic Gulf Stream water	BARENTS BALTIC WHITE
Cyclic advection of cold "fresh" anomaly	BARENTS
Fluctuations of Mediterranean advection water	BLACK AZOV
Expansion of drifting ice-bergs (marine perglacial)	BARENTS
Sea ice dynamics	BARENTS WHITE NORTH CASPIAN
Tidal currents	BARENTS WHITE
Cyclical fluctuations of sea level	CASPIAN
Irregular fluctuations of sea level	AZOV NORTH CASPIAN BALTIC (GULF OF FINLAND)
Cyclic freshening of the basin	BALTIC
Natural fluctuations of river runoff	AZOV BLACK NORTH CASPIAN
Hydrogen sulfide contamination of waters (oxygen deficiency)	BLACK AZOV
Sand storms	AZOV

Fig. 5. Natural phenomena affecting the dynamics of marine ecosystems

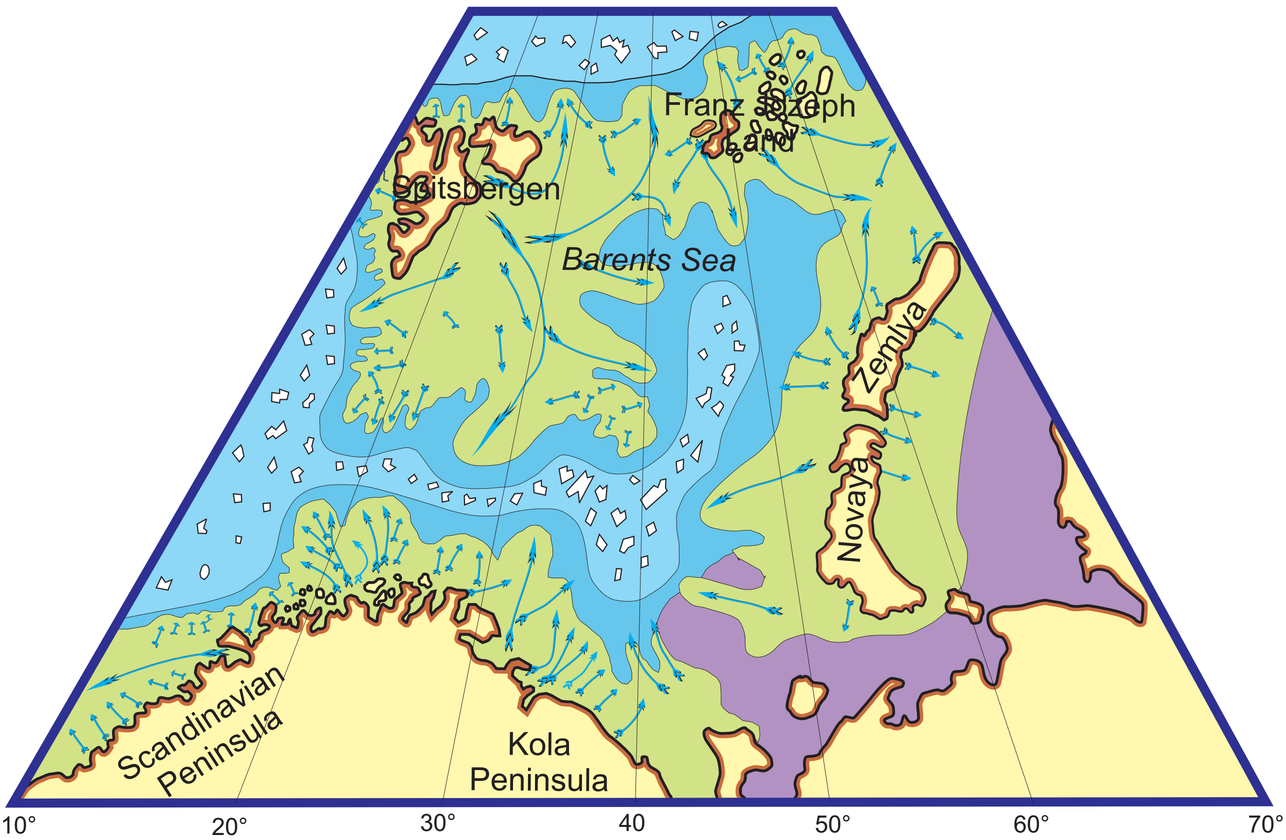


Fig. 6. Probable development of the continental glaciation on the Barents sea shelf during Last Pleistocene (18-20 thousand years ago)

Results of modeling carried out by Prof. Detleff and his group (Potsdam, Germany) proved irregular character of amplitudes and periods of recurrence of natural climatic fluctuations during centuries and millennia. This implies that detected trends (e.g. positive branch of the North-Atlantic Current) may quickly switch to the opposite phase (cooling instead of warming). Coincidence of natural recurrent fluctuations in abundance of fish year-classes and climatic changes in time adds to the complexity of the problem and may produce unpredictable effects.

Every sea is characterized by its own peculiarities of natural changes manifestations on the global scale. In the high latitudes, and especially in the Barents Sea, organisms receive nearly annual dose of solar irradiation during so called Polar day. The anomalous doze of ultraviolet irradiation through the so-called holes in the ozone layer may damage genetic resources of algae and other hydrobionts.

Joint studies of *MMBI* and *the Alfred Wegener Institute of Polar and Marine Studies* (Germany) experimentally proved destructive effects of ultraviolet irradiation exceeding admissible threshold (Dring et al. 1996). The danger of ultraviolet irradiation is in its strong destructive impact on all systems of the biota from impact on the cellular level (DNA and mechanisms of protein synthesis) to ecosystem level (disappearance of less resistant species). Under the influence of high doses of ultraviolet irradiation the growth rate is considerably slowed down, stagnated and plants die off (**Fig.** 8). Ultraviolet irradiation has exceptionally dramatic impact

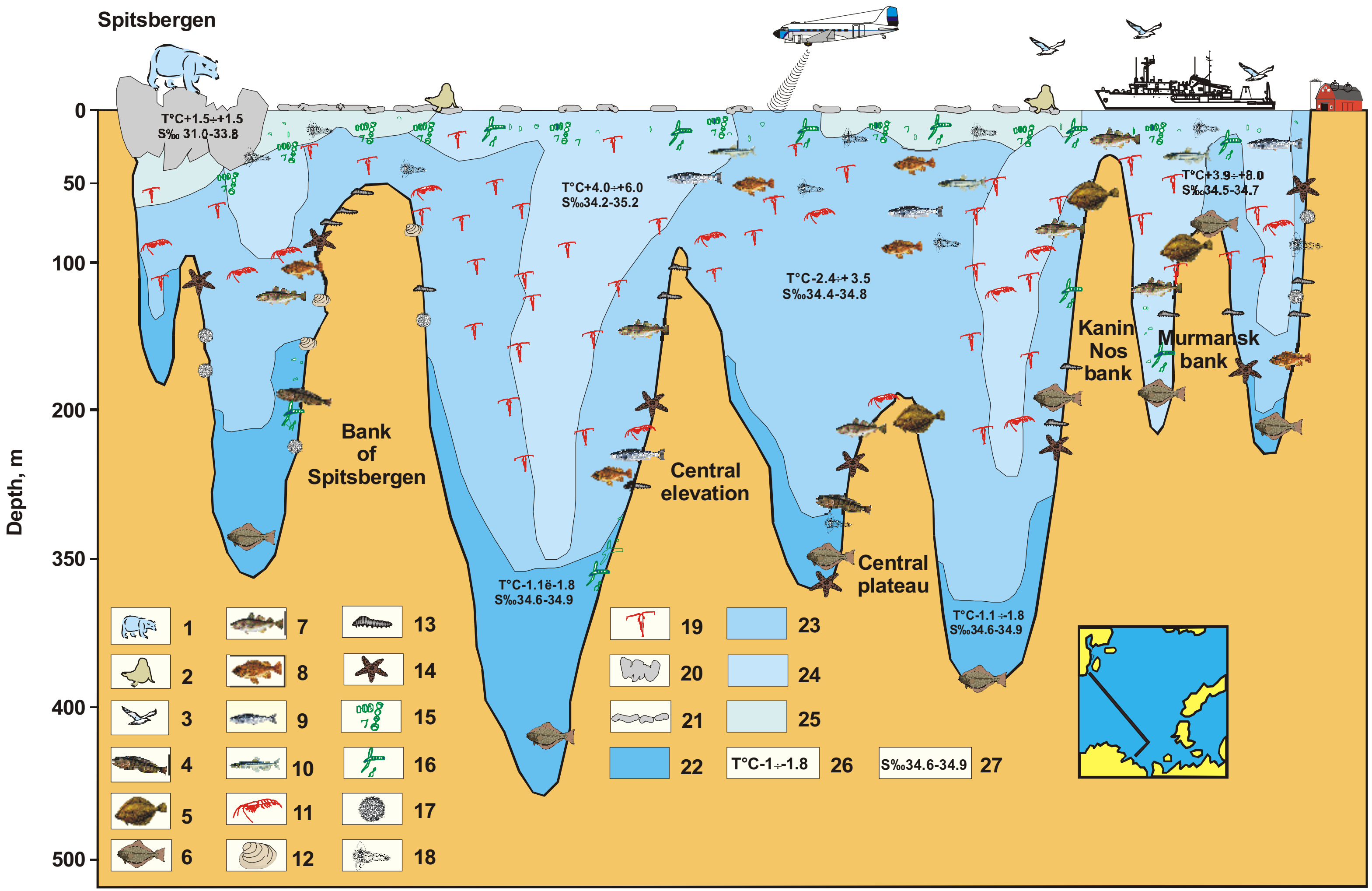


Fig. 7. Structure of the glacial shelf ecosystems (the Barents sea)

The habitat of: 1. polar bear; 2. marine animals; 3. birds; 4. wolffish; 5. plaice; 6. halibut; 7. cod; 8. perch; 9. salmon; 10. capelin; 11. shrimps; 12. scallop; 13. polychaete worms; 14. cushion stars and basket stars; 15-16. diatoms and Mastigophora class; 17. sea urchins; 18. sea butterflies; 19. Calanus and Copepoda subclass

Other symbols: 20. icebergs; 21. sea ice; 22. near bottom waters of Arctic; 23. coastal waters; 24. Atlantic waters; 25. Arctic waters; 26. The Barents Sea waters and water temperature; 27. water salinity

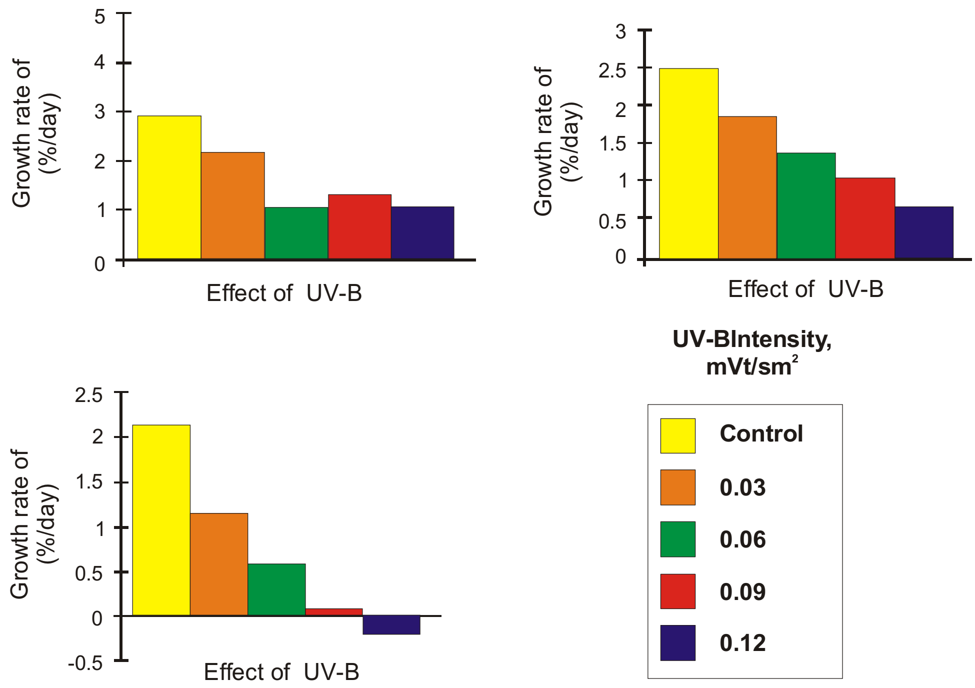


Fig. 8. Ultraviolet radiation impact on the early stages of development of macrophytes

on organisms at the early stages of their life-cycle. Natural level of ultraviolet irradiation that have been observed for last few years significantly (for some species of algae 80%) hinders algae growth rate and reduces natural reproduction capacity of nearly all mass species of algae in the Barents Sea.

The essential role of the Atlantic Ocean for understanding of the processes in the European seas deserves consideration from the geographic viewpoint (**Fig.** 9). One of the crucial factors determining productivity of the Northern seas is temperature and salinity balance in connection with the advection of Atlantic waters. Seasonal and long term dynamics of currents and frontal zones is, in many cases, the crucial factor in marine biota modifications.

Salinity anomaly in the North Atlantic waters and in the Norwegian-Greenland basin in 1970–1980s stands out against the background of the other natural phenomena influencing ecosystem dynamics (Belkin et al. 1997). The North-Atlantic Current salinity anomaly reached the Barents Sea in 7 years after entering the scene (**Fig.**10). The advection of cold fresh water is to be blamed for annual minimum and maximum salinity and temperature on the sea shelf.

Climatic fluctuations occurring during one century or stretching over a number of centuries play an important part in the cycle of biota (**Fig.**11, 12). Some unfavorable climatic changes (cold hydrological years) are known for their particular pattern of occurrence (11, 21, 33, 90 years and longer periods). For instance, normally ice free Kola Bay froze 5 times during the 20th century (1902,1933,1965,1998,1999) and anomalous icebergs deviations up to 1000 km off the habitual drifting route in the Barents Sea took place (**Fig.** 12). 1977–1980 cooling caused reduction of the main Barents Sea fish species stock abundance and decline in fisheries (Yaragina et al. 1996). This cooling is confirmed by Arctic species expansion (Arctic cod) further to the west of the Barents Sea.

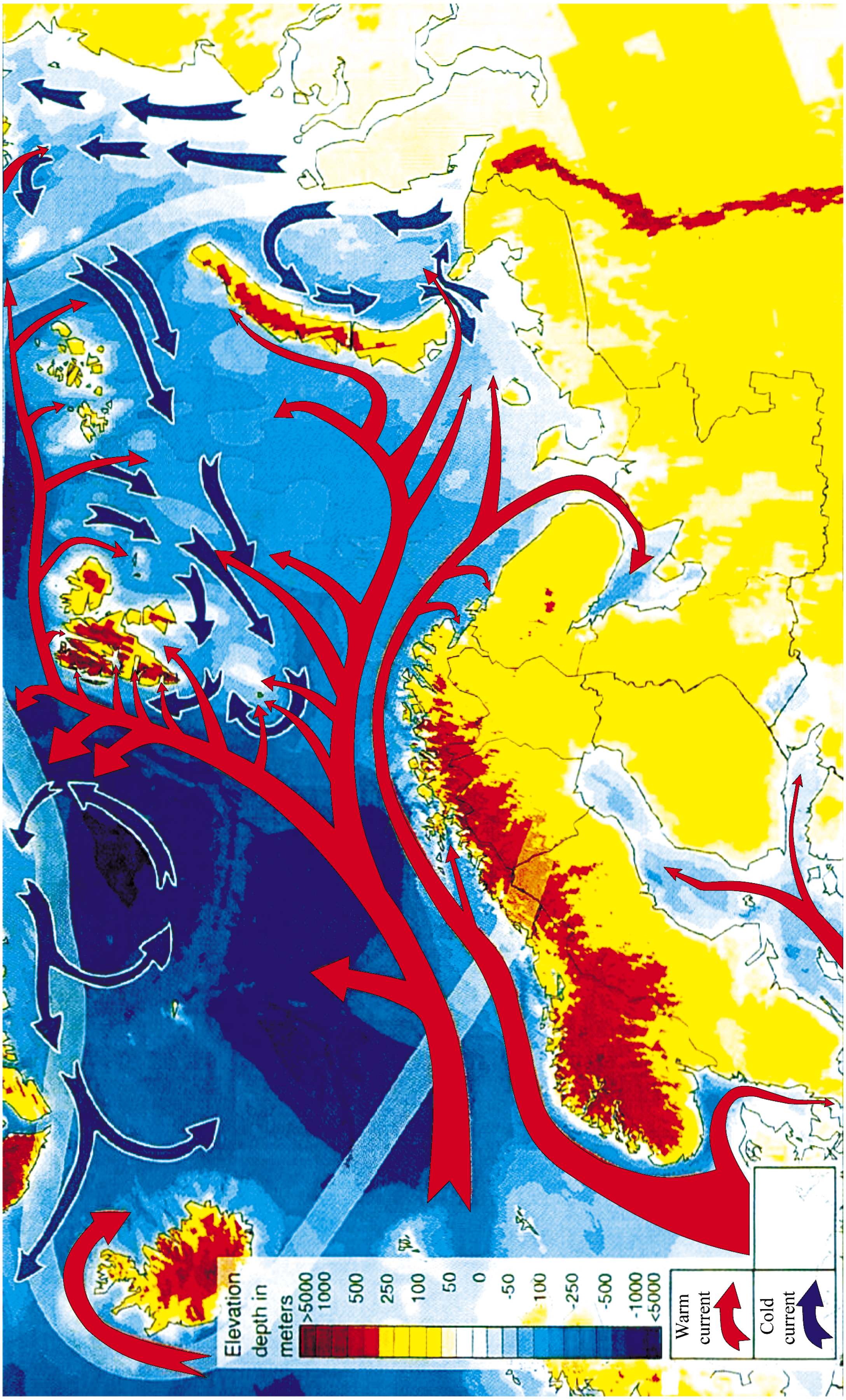


Fig. 9. Advection of warm Atlantic water of the Gulf Stream system

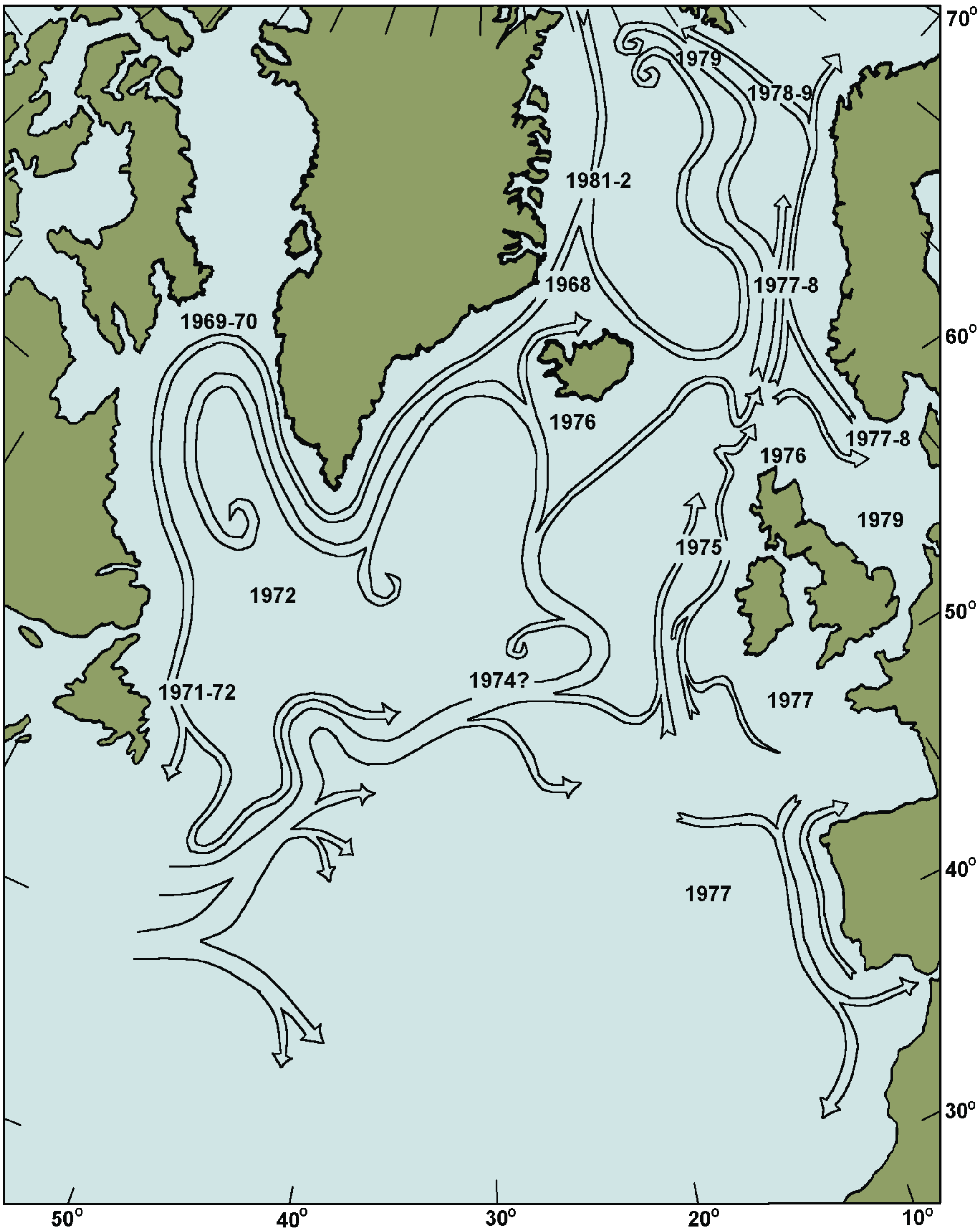


Fig. 10. Shifts of the salinity anomaly in the Atlantic in the 1970s (by Belkin et al., 1997)

Hydrochemical balance, especially salinity, plays an important part in the isolated Southern seas and in the Baltic Sea. The Caspian Sea and the Azov Sea represent brackish reservoirs with salinity 10–13‰ which is 3 times less than ocean water salinity (35‰). The Black Sea typical salinity is 15–19‰. The Baltic Sea basin waters salinity varies from 5–9‰ during the periods of freshening to 10–14‰ during the periods of salinization.

On the whole, water salinity of the above mentioned seas is 2 to 4 times less than in the Barents Sea and any variation of salinity brings drastic changes into the life cycle of local biota. The Azov Sea deficiency of fresh water outflow resulting from rivers run-off regulation, caused 3‰ increase in average salinity (**Fig.**13). This is only one decimal fraction of ocean waters regular salinity, but for the brackish sea it is one third of the normal value. This resulted in outburst of jellyfish biomass in the Black Sea. This is not an isolated event. Advection from the Atlantic ocean and related to it balance of salinity is one of the most important natural factors determining the Baltic Sea ecosystem productivity. In the periods of freshening, as it happened at the late 1970s, production of marine fauna, especially of cod, goes down (Antonov 1998).

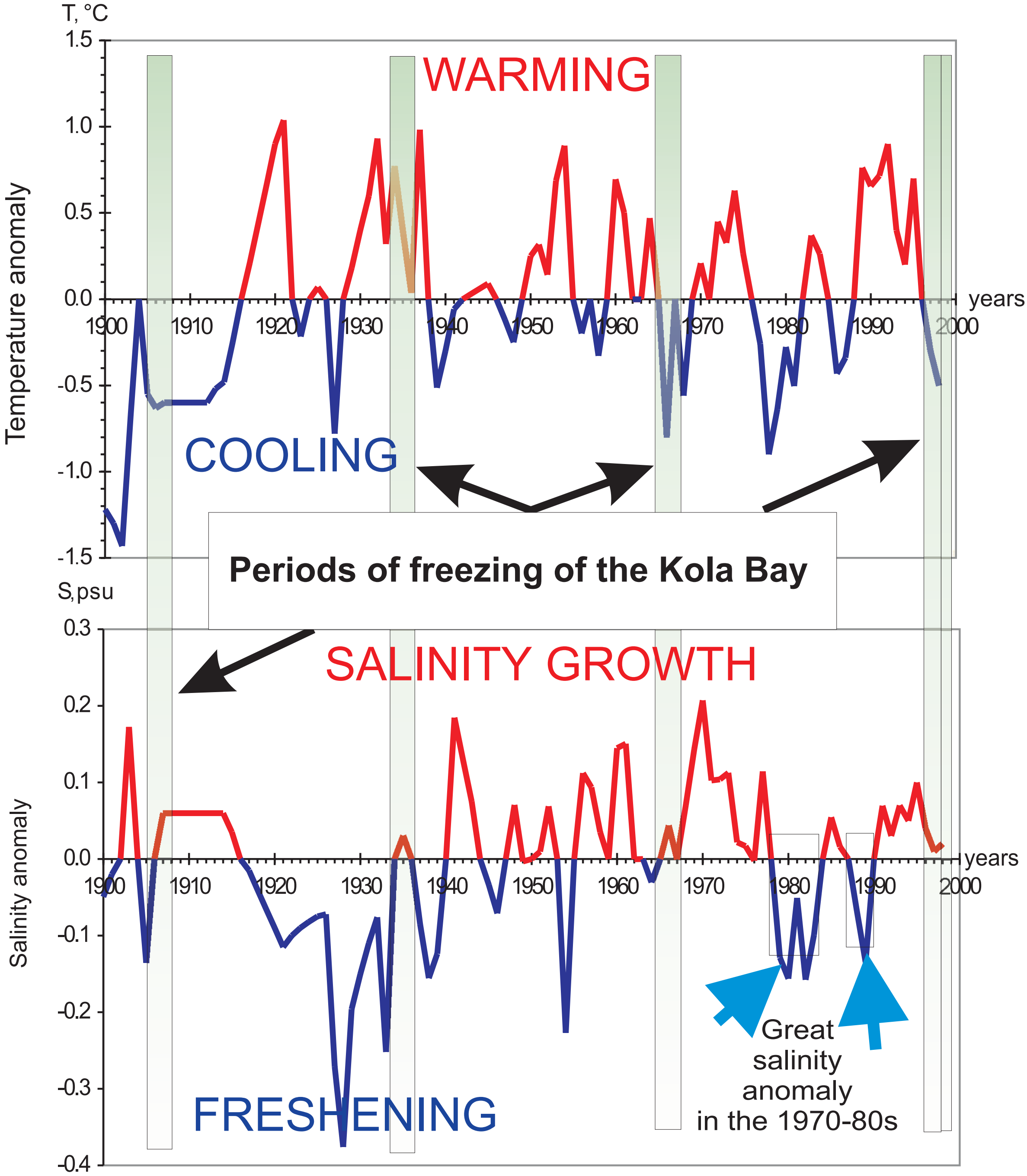


Fig. 11. Long-term changes of temperature and salinity in the Barents sea. 0 to 50 m depth

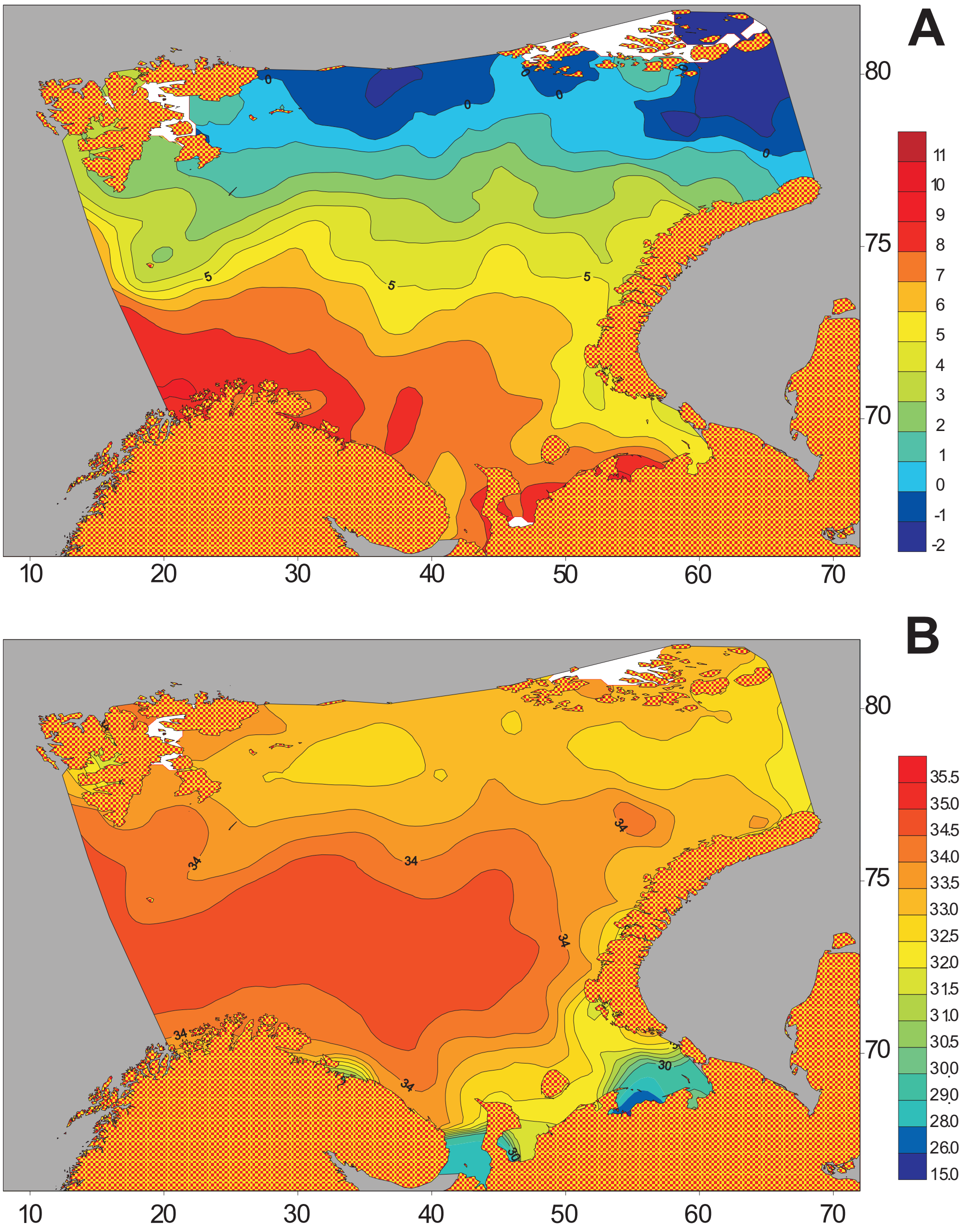


Fig. 12. Long-term average temperature (A) *and salinity* (B) *in the Barents Sea. September. Surface horizon 0 meters (Climatic Atlas of the Barents sea 1998)*

There are some other hazardous natural phenomena in the Southern seas. The Azov Sea shallow water is most exposed to sandstorms and extreme fluctuations of sea level. Sea level fluctuations of the isolated Caspian Sea are even more remarkable (**Fig.**14). Observations during 1830–1997 show that sea level fluctuations range reaches 3 m with annual changes of up to 15 cm. This sea level decrease was well known and publicly discussed in the 1960–70s. This was followed by stable increase of sea level in 1978. In 1997, another (now 30 cm) decrease followed.

Such large scale changes in regime of the Caspian Sea, resulting from climatic changes, alter the ecosystem. Fish yield in the North of the Caspian Sea and Volga River delta has changed considerably (**Fig.**14). Relative sea level increase naturally fosters bioproductivity of the given reservoir.

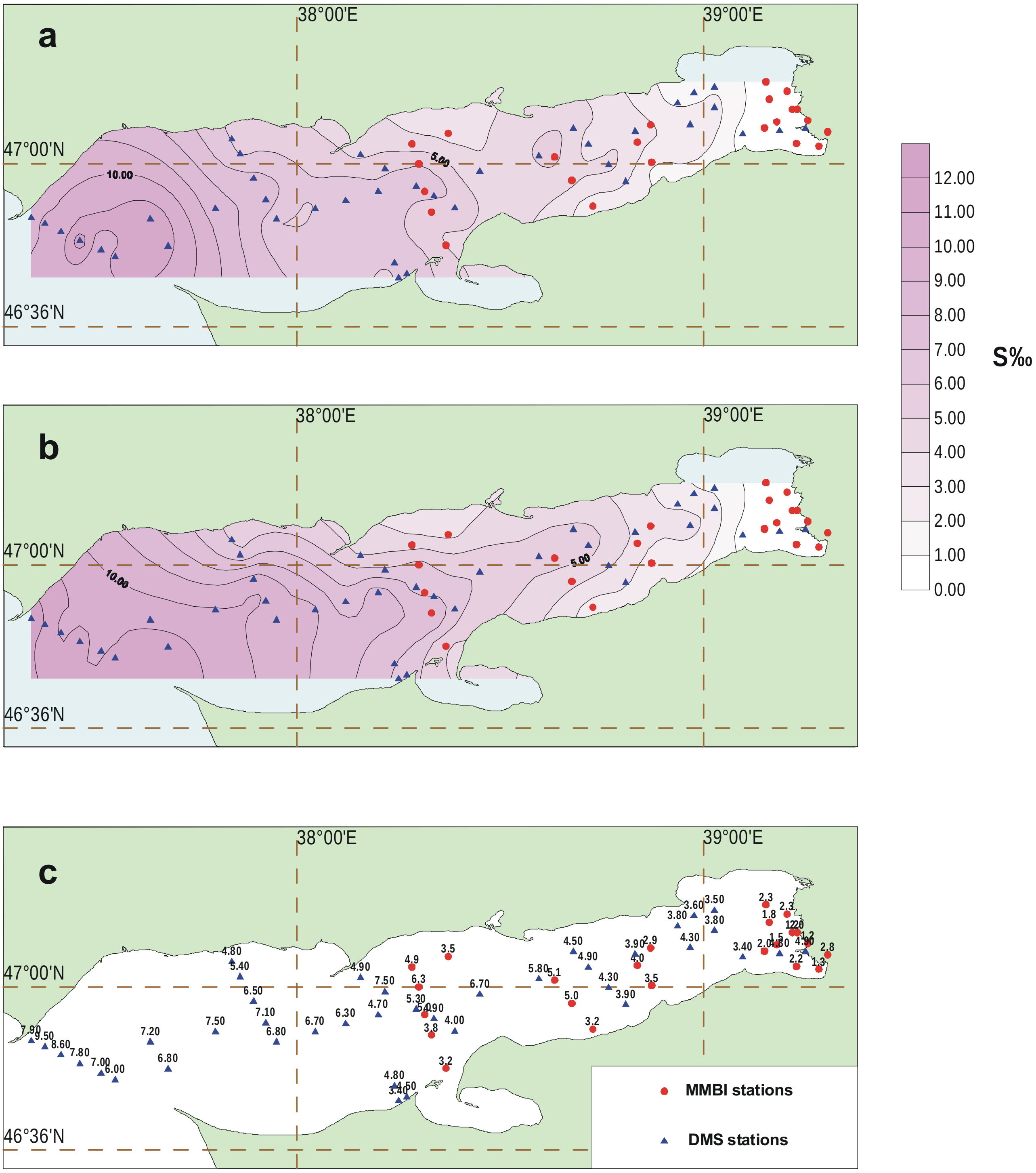
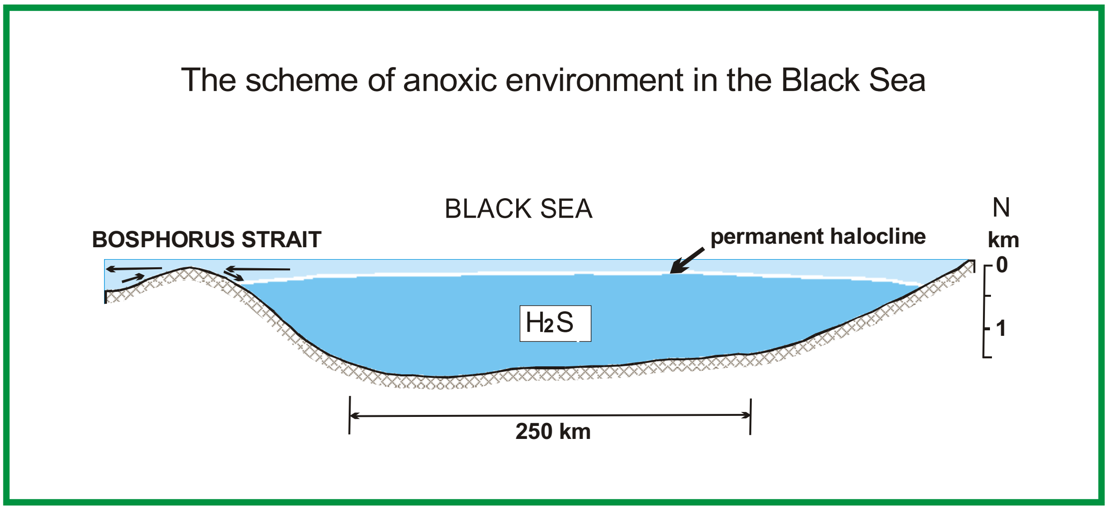


Fig. 13. Distribution of water salinity on (a) surface, (b) near the bottom and depth in meters at the stations in the Taganrog Bay of the Azov Sea (by summarized data of the MMBI expeditions and the Don River mouth stations (DMS), June 1998)



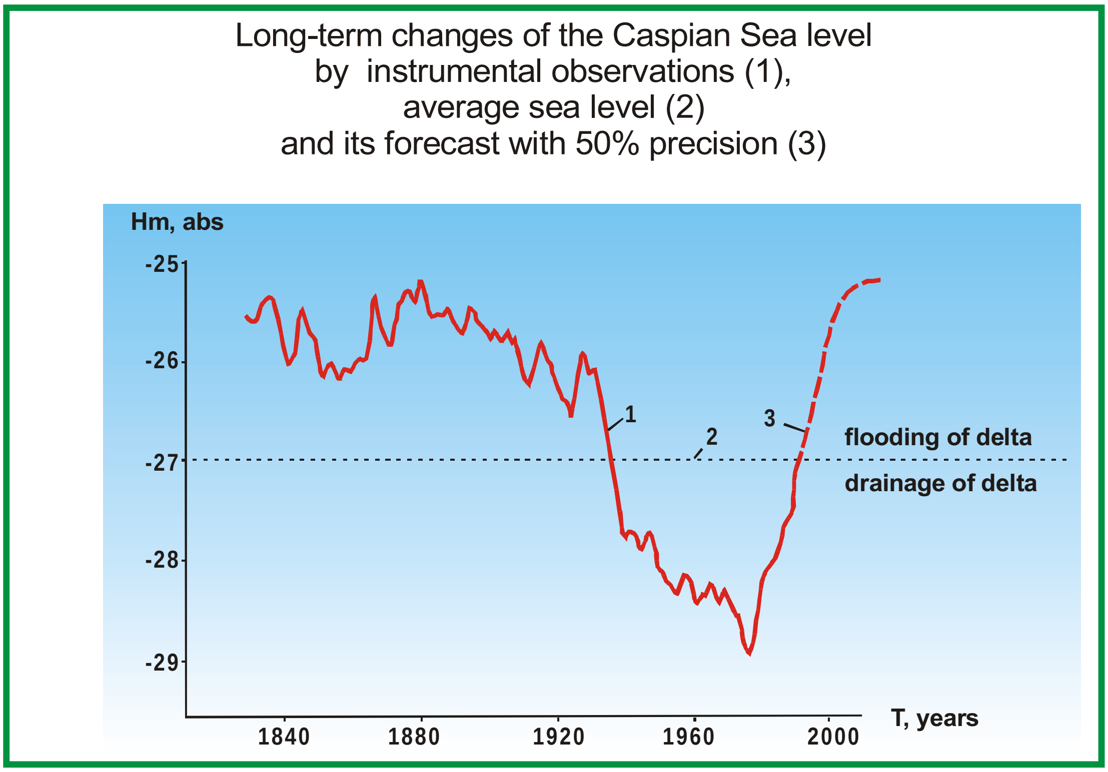


Fig. 14. Natural anomalous phenomena (by Demaison and Moore 1980, R K. Klige 1984)

It is noteworthy that the Black Sea is one of the biggest containers of hydrogen sulphide which saturates its waters at depths below 70–150 meters (**Fig.** 14). This is the reason for absence of rich benthos, characteristic of other seas, beyond these depths.

The complete answer to the question «What parameters cause changes in species dynamics even for one given species?» will require data on physical and chemical parameters of the species environment, efficiency of food supply, competitors, predator and parasites influence on its life cycle. Also information on how all the variables influence reproduction, mortality and migration will be needed.

CONTEMPORARY STATE OF MARKETABLE ECOSYSTEMS

Marine biota and ecosystem structures are normally described by variety of species, number of specimens, degree of species domination, interrelations of different types such as trophic, competitive, etc. (**Fig.**15). Let us first consider the state of the top elements of marine ecosystem. This includes sea mammals and sea birds, many of which are being protected on account of their scarce populations (**Fig.** 16).

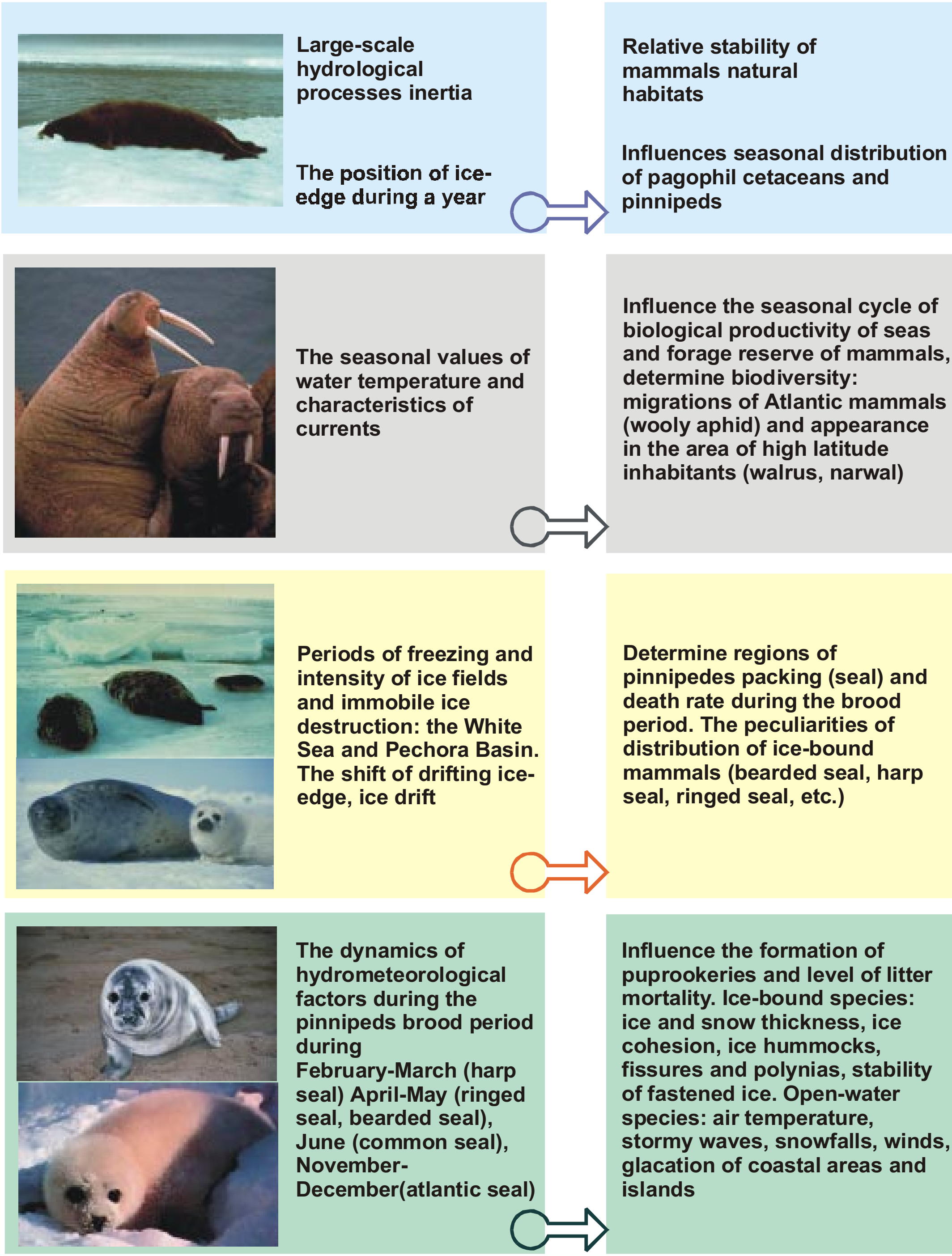
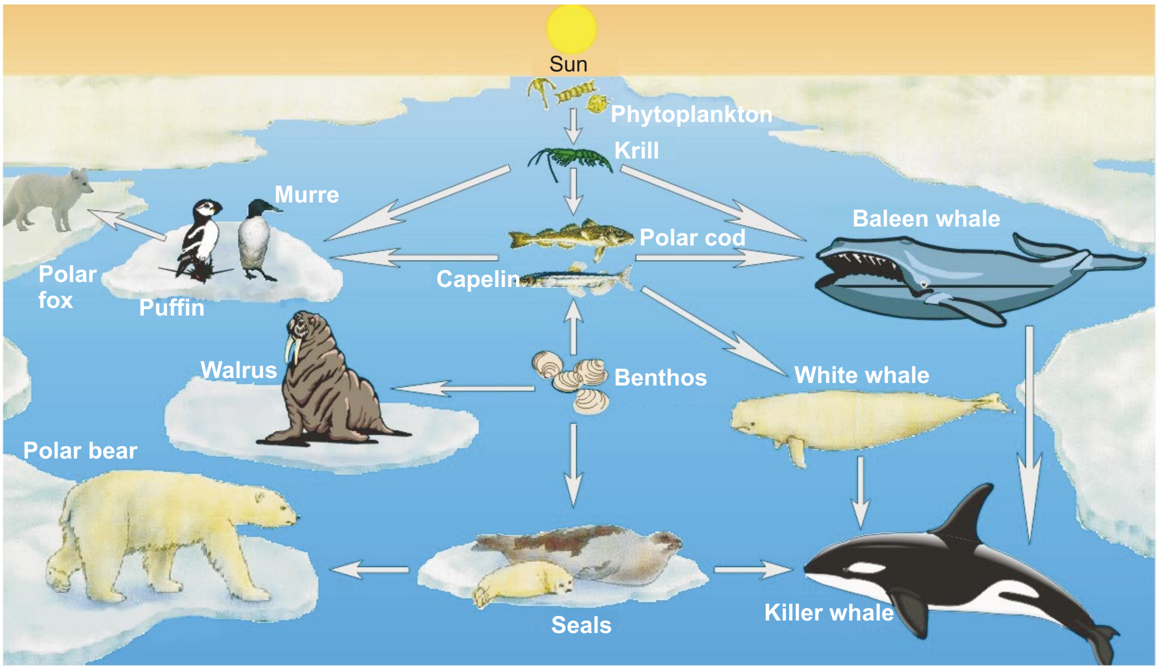


Fig. 15. Impact of the climatic factors on the state of marine mammals populations



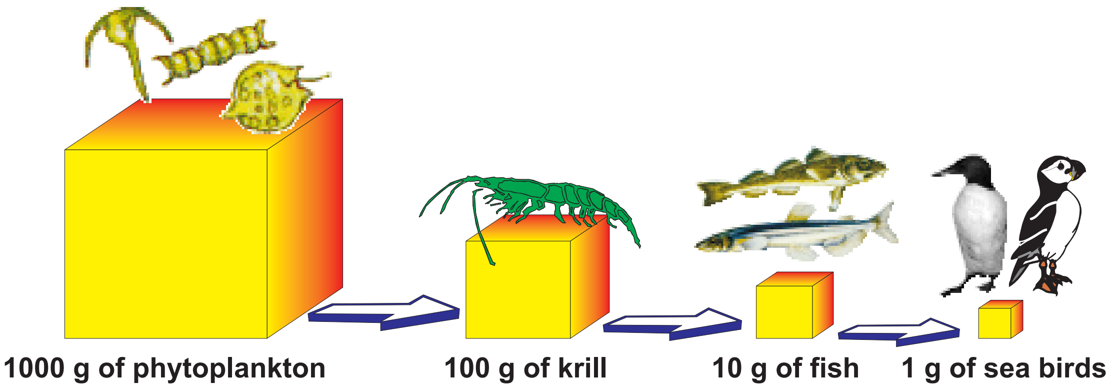


Fig. 16. Structure of the ecosystem of the polar seas. Universal pattern of food chains

MARINE MAMMALS

The history of whaling, which began in the 17th century, serves as a good example of the irreversible nature of biological changes when some species are put to the verge of extinction (**Fig.** 17). By the beginning of the 20th century, whale hunters nearly eliminated right whales and blue whales in the Arctic. Right whales stocks now stand at only 5,000–6,000 individuals. Many whales are registered in the Red Book.

In the middle of the 20th century, hunting shifted to the Antarctic. By the end of this century humpback whale stocks have been reduced to 3,000–5,000 individuals which constitutes only 3–5% of their original number. Finwhale population originally consisting of 500,000 individuals was reduced by 95 %. Only 200–1000 of blue whales survived, though their original stock had been 250,000 (Mallvitz 1998). Despite protection under the law since 1965 their population has not recovered. International Whale Protection Commission prohibited hunting of most of the whales since 1986. However, the Commission failed to stop hunting small whales (dolphins too).

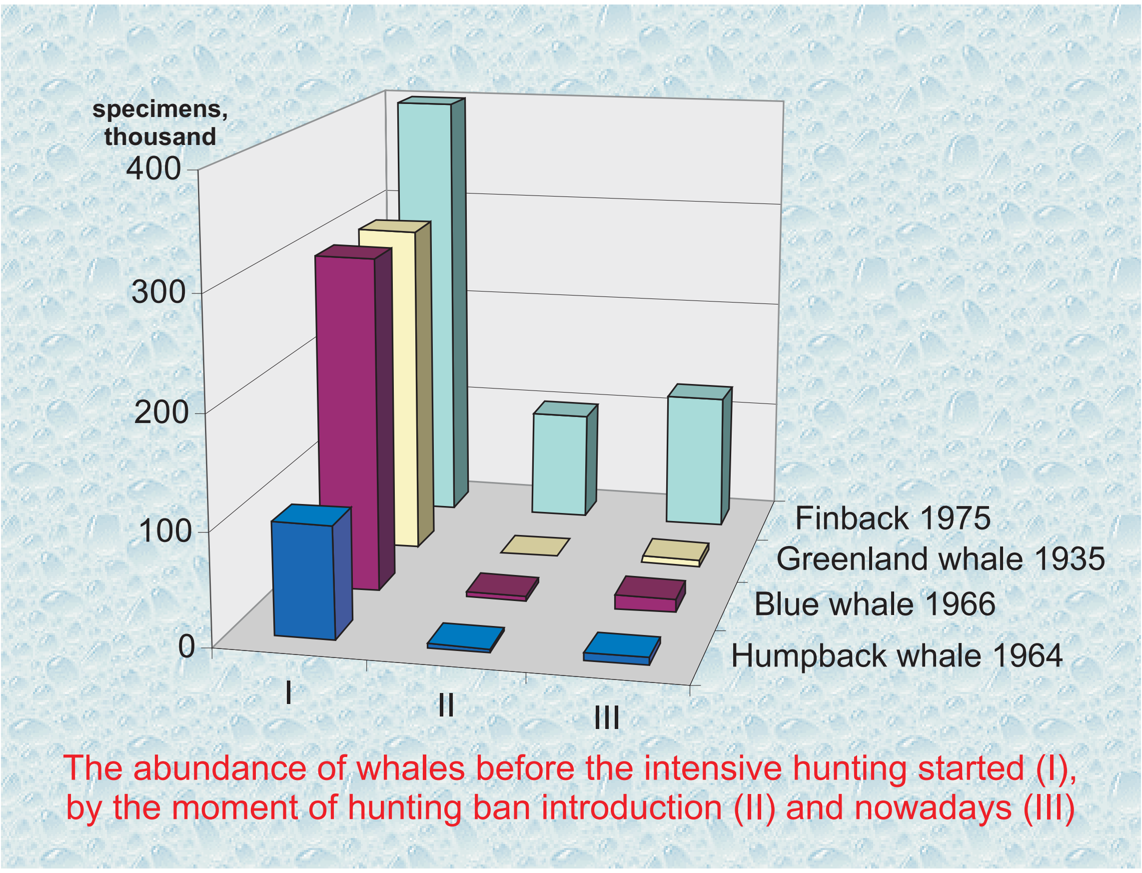


Fig. 17. Whaling

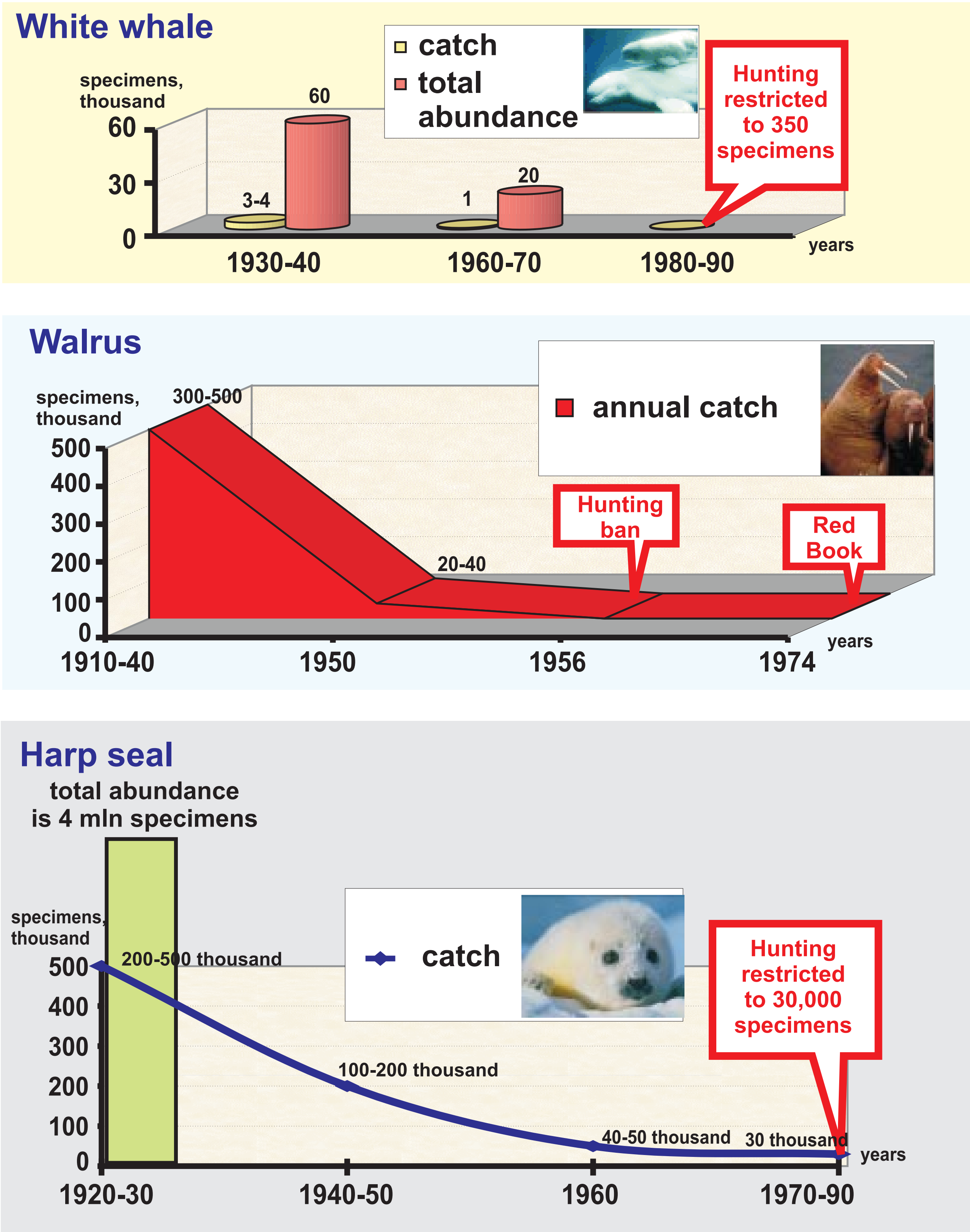


Fig. 18. Dynamics of marine mammals abundance

Lesser whales hunting developed the same way in the1930-60s. In 1938–1964, the Norwegians captured 78,000 smaller whales, mainly lesser rorqual (93%). In 1958, they captured in the Barents and adjacent seas the biggest amount ever, 5,000 individuals (**Fig.** 18). Intense regular hunting in the areas of stable concentration of animals resulted in a sharp decrease in their abundance and a consequent decline in whale hunting. White whale population has decreased by 3 times as compared to the levels of the 1930-40s (from 60,000 to 20,000 specimens). During that period the annual yield equaled to 3,000–4,000 specimens. Later hunting was restricted to 350 individuals until it was finally banned. In the Black-Azov seas basin cetaceans are represented by dolphins (**Fig.** 19). Their rather limited and urbanized environment is continually degrading. There were 1 mln dolphins in the Black Sea at the beginning of the 1950s. Despite a hunting ban since 1966, their population at the end of the 1980s hardly exceeded 50–100,000 specimens (Fashchuk 1998). Common porpoise had a commercial value in the 1920/40s and yields consisted of several thousands specimens (Geptner et al. 1976). Nowadays this species is extremely rare and therefore is not subject of study. There is little hope for recovery of its population on account of the ruined forage (sharp decrease in abundance of goby and other important food items). An even more prominent role in the European seas of Russia is played by *Platanistidae* family. They are competing with people for the same food resources and therefore reducing fish stocks. Norwegian experts have focused on artificial control over the populations of seals for fisheries' sake. Many of Canadian experts agree to kill 510,000 of harp seals and 30,000–40,000 of grey seals in order to preserve population of cod. However, such take might be rather hazardous for the population.

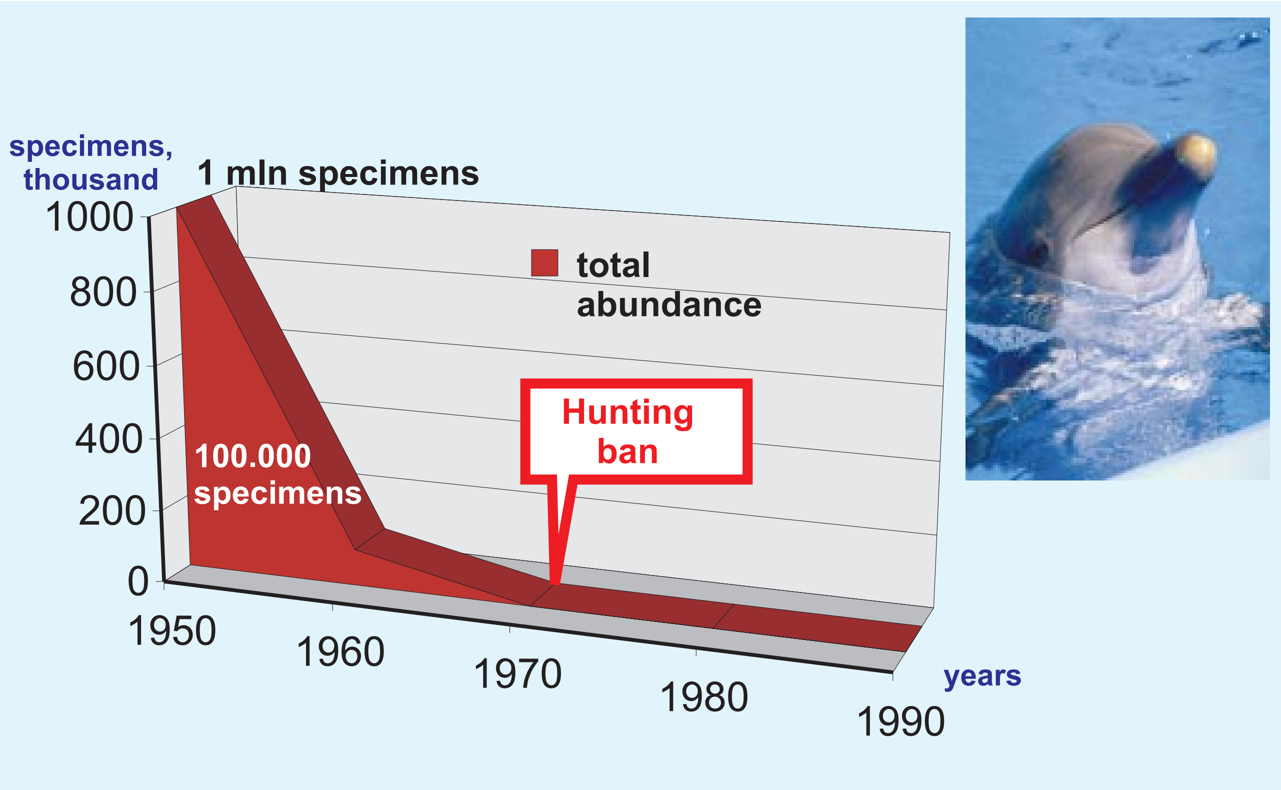


Fig. 19. Dynamics of dolphins abundance in the Azov Sea and the Black Sea basin during different periods of the 20th century

MMBI long term studies (Mishin and Stepakhno 1997) at the oceanarium showed that daily fish ration of seals is about 5 % of the animal weight. Seals also proved to prefer more nourishing fish such as herring, Atlantic mackerel and capelin to cod. The diet of the harp seal includes 53 species of fish and 54 species of invertebrates. These seals are basically omnivorous. Since the natural survival rate of cod juveniles may vary from 5 to 10 fold and seals graze upon predators of capelin and cod, it would not be unnatural to hypothesize that an increase in abundance of seals may even cause an increase in abundance of stocks of certain species of fish.

Statistics clearly show a progressive degradation of some *Platanistidae* populations because of hunting at the same time as fish stocks are declining. Acute shortage of fish in seals diets brought profound changes into the migration routes and was the cause of peculiarities of their life cycle (Kavtsevitch and Erokhina 1996). From the 19th up to the middle of the 20th century, Atlantic walrus hunting was absolutely unrestricted and its population declined from many hundred thousand to several dozen thousand specimens (Bytchkov 1976). In the 1950s, hunting of such Arctic residents as Polar bear and Atlantic walrus, inhabitants of drifting ice-fields and coast line of Novaya Zemlya, Franz Josef Land, Spitsbergen, was banned altogether. Walrus hunting was banned only in 1956, and in 1974 this walrus subspecies was registered in the Red Book.

By the end of the 20th century, gray and common seal alongside other representatives of Polar *Platanistidae* were registered as rare or protected species (Fig. 20). In the Southern seas the unfavorable environment and lack of protective measures have pushed the sea mammals to the verge of extinction. This also is the case for the monk seal in the Azov Sea.

The story of harp seal, which has been the most popular species of Platanistidae family in the Northern seas, is notable example. At first its population had been 4 mln specimens. During the 1920–30s seal hunters captured 200,000–500,000 specimens of all ages annually (Yakovenko 1967, Nazarenko 1984). Obvious degradation of the species in the1960s led to the imposition of a series of bans and restrictions on sealing. Nowadays only the whitecoats are the object of hunting. The hunting quota is about 30,000 specimens. A consequence of this harvesting pattern is an alteration of the stock age structure, i.e. the population is getting older as the number of young mature females is decreasing. Probably, harp seal whitecoats hunting should be banned as has happened in the case of the Caspian seal whitecoats.

Caspian seal (Phoca caspica) is endemic originating from the north and the only marine mammal of the Caspian Sea. The population of this seal became very soon distinct but preserved some biological characteristics such as bearing of pups on ice. In the 1930s yield was over 160 specimens (Ivanov 1992). After the World War II hunting was still on the high level (up to 100,000 individuals per year). In 1997, there was a serious decrease in yield (4,000 individuals) (**Fig.**21). Caspian seal pup hunting has been banned since 1998.

Reduction in abundance of representatives at the top level of the pelagic food web, sea mammals, inevitably undermines stability of the related ecosystems, and, in the end, results in their poor productivity (*Ecology of birds and seals in the seas of the North-West of Russia 1997*). It is well worth mentioning, that *Asclepiadasea* family and *Cetacean* family have low rates of natural reproduction. The reproductive cycle of such species as walrus and Greenland whale lasts for at least 3–4 years. The lifecycle of walrus unlike that of whales is affected by hydrometeorological factors. This is because representatives of *Asclepiadasea* family have to

FISHERY:
overcatch of the fishery reserves
HUNTING:
selective catch of pups
POACHING

Undermining of the forage basis, alteration of migration routes, food priorities, death of the animals in the hunting gears; reducing of the abundance, alteration of the age structure (ageing of the population), decrease of recruitment

CONTAMINATION:
(oil spill, domestic waste) impact of pollutants through the food chains

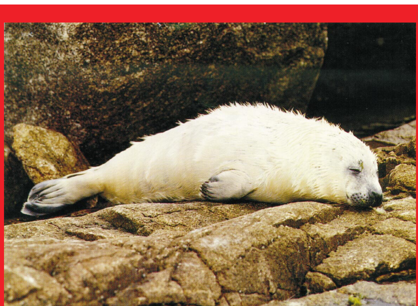
Death of the animals; destruction of the immune and reproductive systems, lowering of the reproductive functions, the irreversible degradation of the population

NAVIGATION OF THE ICE-BREAKERS' FLEET:
Winter-spring

Destruction of the ice fields in the areas of the pinnipeds pups layouts, death of the pups

ECONOMIC ACTIVITY:
Construction (including hydro-electric stations), fishery, procurement of sea-weeds and invertebrates

Leaving of traditional brood sites, death and injuring of the animals by catching gears and underwater communications



TECHNOGENIC NOISES:
Shipping, drilling platforms, geophysical experiments and training military

Increase of the number of the pups left by the females, diseases caused by stress, infrasound impact on communication and migrations of Baleen whale

Fig. 20. Anthropogenic stress on Arctic marine mammals

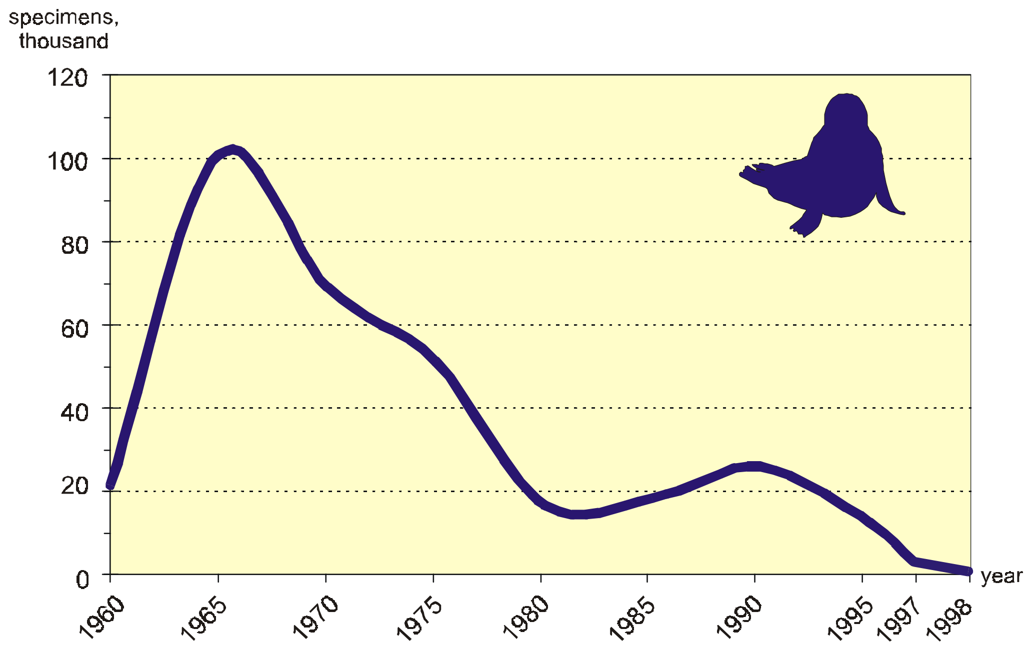


Fig. 21. Catch of seals in the Caspian Sea basin (by Ivanov et al. 1999)

leave water and go to the shore, ice or islands during the breeding season. That connection between the life cycle and climate is the reason, why the climatic pattern should be given serious consideration when modeling ecosystem dynamics.

MARKETABLE FISHES

Despite all efforts the unceasing decline in stock numbers and yields in the seas of the European part of Russia is the reality (**Fig.** 22).

The Black Sea. Average catch in the 1970–80s in the Black Sea amounted to 200,000 t. Approximately 90% of the catch consisted of sprats and anchovy (Dachno et al. 1997). The catch of such valuable marketable fishes as Black Sea scad, flounder, mackerel, mullet, ballan wrasse has declined an order of magnitude.

The catch pattern has changed considerably on the whole, for in the 1950s over 50% of the yield was comprised of valuable marketable species. 37% of them were such pelagic predators as bonito, Atlantic mackerel, Black Sea scad, bluefish. There were also considerable catches of Black Sea turbot, mullet and other members of Mullidae family. Only 36% of the catch consisted of short-lived pelagic species such as anchovy and sprat. Catch of migrants from the Marmara Sea, bluefish, bonito, Atlantic mackerel in the 1970s went down to only hundreds of tons. Large individuals of Black Sea scad are not evident catch any more and there are considerably decreased catches of Black Sea turbot, mullet and other members of the Mullidae family.

Introduction of Ctenophora into the reservoir resulted in an abrupt reduction of anchovy stocks, Clupeonella, Mullidae and some other marketable fishes (Gubanov and Serobaba 1997).

The Azov Sea. The Azov Sea environment is one of the world's most fertile fishing grounds with over 80 kg of fish per 1hectar. The peak catch was registered in the 1860s right before the beginning of continuous fisheries decline (Troitsky 1973). Yet catches of such valuable marketable species as sturgeon, zander, bream, sea-roach, zarthe, etc. still amounted to 150,000–300,000 t per year in the 1930–50s (**Fig.** 23–25).

Nowadays the species diversity of these marine living resources have declined dramatically (Makarov and Semenov 1996). For example, the yield of traditional for the Azov Sea sea-roach in the 1930s was 20,000–25,000 t and common carp 74,000 t per year and from 1990–1996 catches of sea-roach declined to 100–250 t per year and catches of zander were only 1,000–3,000 t. The situation with sazan stock is nearly the same, though in this case the short fall is partly compensated by rearing of common carp at aquafarms (**Fig.** 23).

The fate of sturgeon family causes concern. During the 1960s sturgeon catch in the Azov Sea reached 10,000–14,000 t (Troitsky 1973). However, by 1937 in the Azov Sea and in the mouth of the Don River the catch comprised 7,000 t and by 1997 it was down to 450 t. The 10 –20 fold decline in catches of sturgeon family, also typical of the other fishes, is far too obvious.

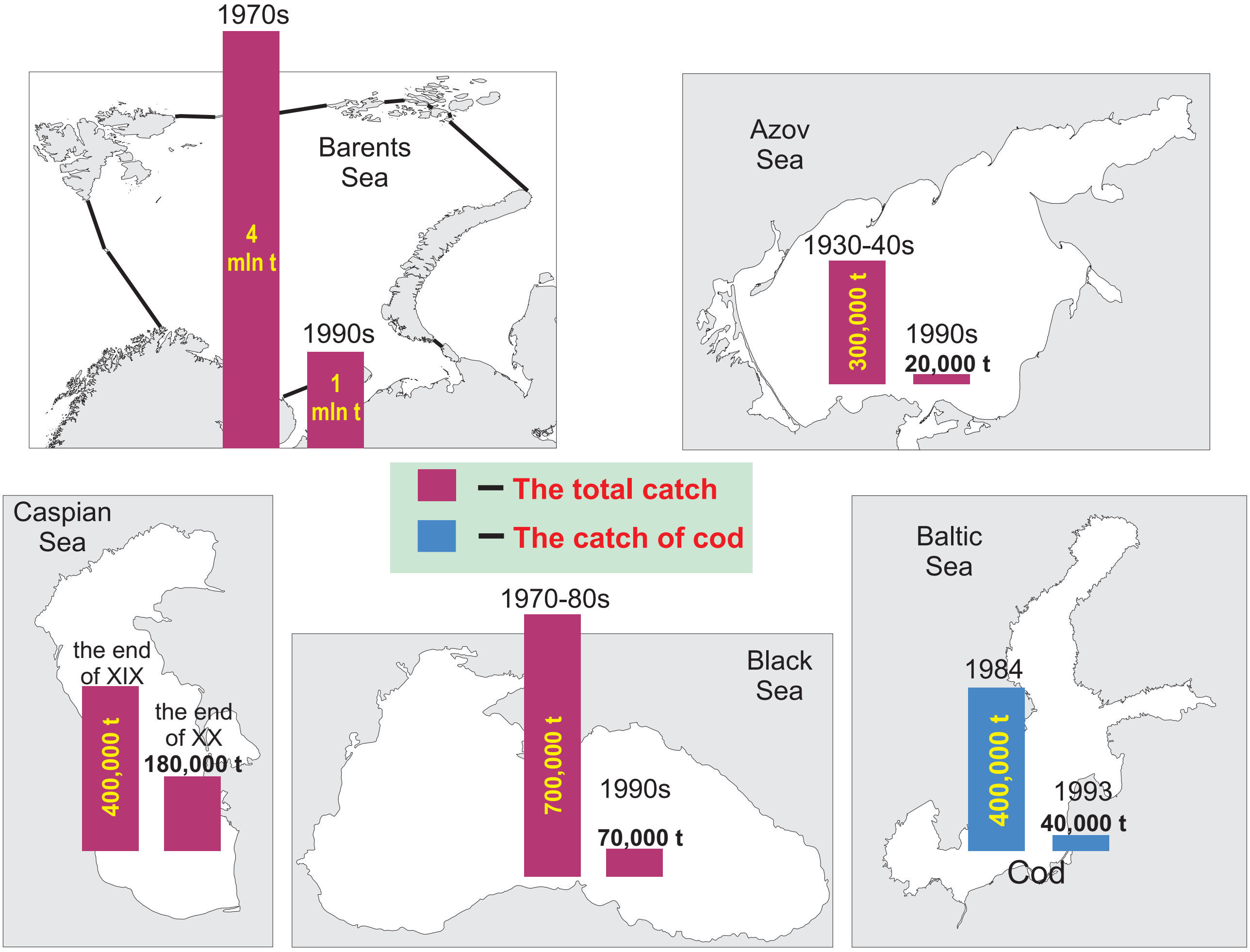


Fig. 22. Total catches of fish in the seas of the European part of Russia in the past and at present

The catches of the main marketable fish in the Azov basin, tons

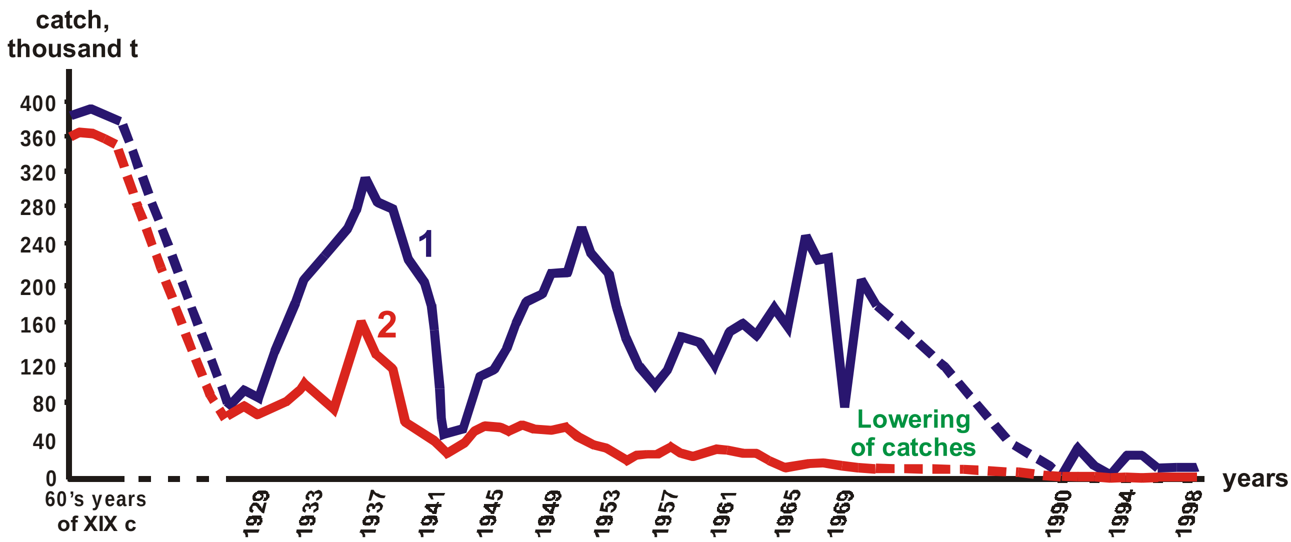
The species of fish	Maximum catches: tons	Maximum catches: year	1990	1991	1992	1993	1994	1995	1996
Sturgeon family*	7300	1937	1012	1021	1006	1202	1224	790	594
Also									
sturgeon			677	759	756	893	874	476	412
starred sturgeon			334	262	246	307	348	312	181
white sturgeon			1	-	4	2	2	2	1
zander	73700	1936	1446	1266	975	699	1092	1367	3135
bream	46500	1936	1715	1663	1564	1387	1025	887	960
sea-roach	18200	1936	182	101	129	140	476	244	244
goby	91700	1957	208	432	106	249	305	130	23
anchovy	142600	1974	43	46	9517	3123	17950	15049	4659
kilka	125800	1982	1370	27055	3018	281	4500	6969	1445
pleuronectidae family	1800	1986	530	403	365	273	263	126	144
haarder	1600	1996	-	-	52	74	365	981	1600
All	523600	1936	6499	31989	16732	7428	27200	26543	12419

* Maximum catches of sturgeon were in 1937, but list of species is missing. The next to maximum catches with list of species was in 1935, when the total catch was 4700 tonns,including:
- sturgeon - 900 t
- starred sturgeon - 2900 t
- white sturgeon - 900 t

The catches of fish by enterprises of the Russian Federation, thousand tons

Year	Salmon	Sturgeon	Herring	Sprat	Big fish: zander	Big fish: bream	Big fish: sazan	Big fish: catfish	Big fish: asp	Big fish: pike	Big fish: other	Big fish: all	Roach	Small fish	Other	All
1990	0.01	11.7	2.0	137.0		13.6	3.7	8.8	-	3.5	0.1	30.7	18.7	9.0	0.02	209.1
1991	0.01	8.5	1.3	124.0	1.9	12.4	4.43	7.9	0.2	3.1	0.1	30.0	17.5	10.0	0.1	191.4
1992	0.03	7.5	1.9	100.5	3.7	15.2	3.4	5.5	0.1	3.7	0.1	31.7	19.5	9.8	0.02	170.9
1993	0.03	4.3	1.4	73.4	2.1	15.9	1.8	3.9	0.2	3.4	0.1	27.4	18.6	6.8	0.1	132.0
1994	0.05	3.2	1.3	77.2	0.8	17.9	1.8	3.8	0.2	2.6	0.1	27.2	15.8	6.8	0.03	131.5
1995	0.05	2.3	1.5	80.0	0.84	18.8	2.2	4.4	0.3	3.2	0.06	29.6	13.7	9.1	0.01	136.2
1996	0.03	1.3	1.9	74.4	0.7	18.2	3.6	5.8	0.1	3.5	-	31.9	14.9	9.5	-	133.9

Fig. 23. Catches of the main commercial fish species in the Caspian Sea and in the Azov Sea (by Volovik et al. 1998, Mazhnik and Scharzkopf 1998)



1 - total catch

2 - catch of the valuable fish

Fig. 24. Dynamics of the main commercial fish species catch in the Azov Sea basin

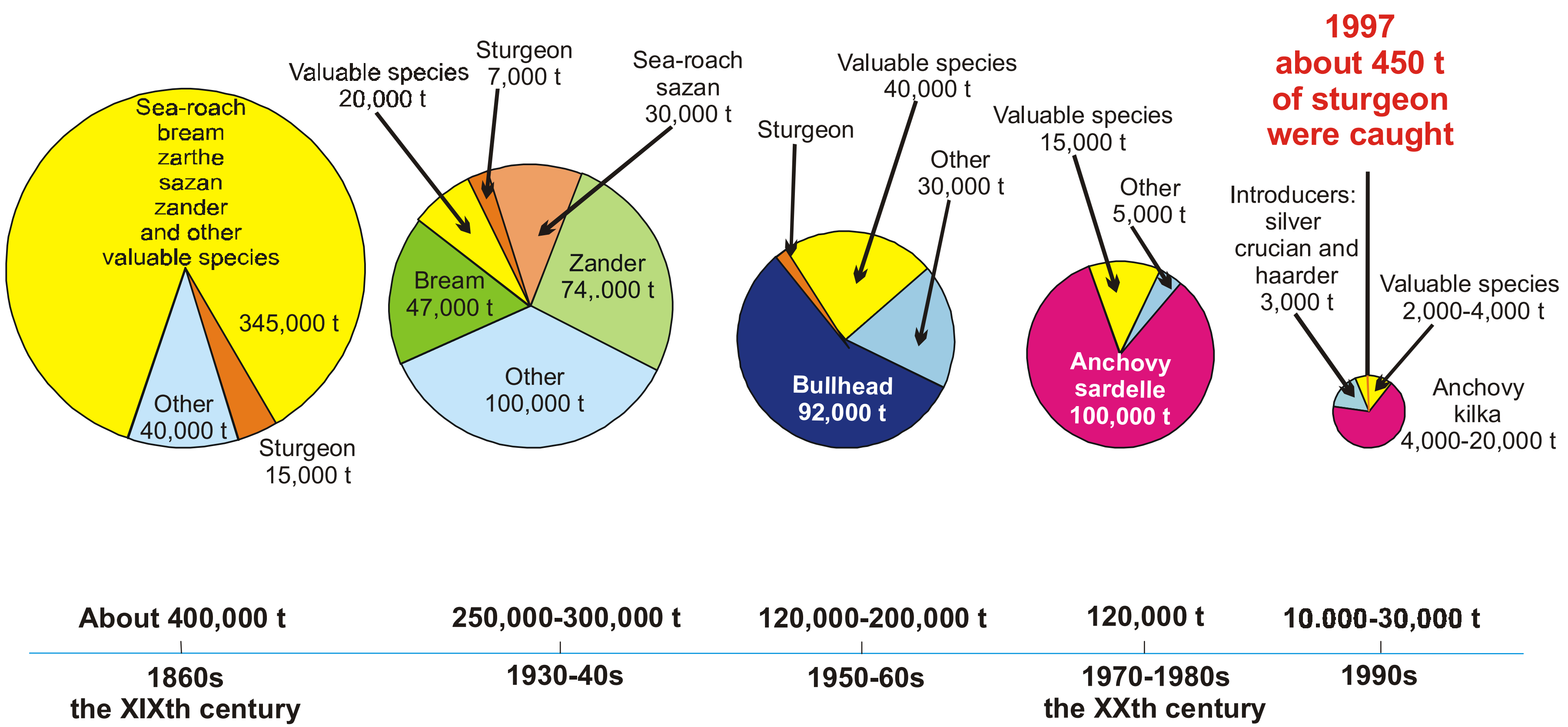


Fig. 25. Dynamics of the main commercial fish species catch in the Azov Sea

Experts of *All-Russian scientific-research institute of fishery and oceanography (VNIRO)* and *Azov Fishery scientific-research institute* found out that sturgeon family reproduction now almost completely depends upon efficiency of aquafarms. While rearing has made it possible to maintain reproduction of the Russian sturgeon, albeit at a low level, stocks of Caspian sturgeon, the great sturgeon are on the verge of extinction (Volovik et al. 1996). Moreover, the maintenance of the genetic diversity in order to preserve the species might arise in the near future.

The Caspian Sea. In many respects a similar sturgeon situation is observed in the northern part of the Caspian Sea and in the Volga River estuary (**Fig.** 26, 27) where over 90% of historical catch of sturgeon family were made. And by 1995 the world catch of sturgeon was only 6,610 t (by *FAO*) with the catch in the Caspian basin 4,400 t (70%) including Russian 2,300 t. At the end of the 19th century yield in this area was 40,000 t.

Sturgeon family stock dynamics causes great concern because their stock has declined 2 times since 1991 (Vlasenko 1997). There is a distinct trend of decrease in parental stock migrating to the rivers of the Caspian basin during the reproductive period is observed as well as a general decrease of the stock in the sea. Migrations of sturgeon to the spawning areas decreased from 371,000 specimens in 1991 to 70,400 specimens in 1996; migrating stock of Caspian sturgeon decreased from 234,000 to 89,800 specimens (Chodorevsky et al. 1997).

Major sources of recruitment for the sturgeon family are natural reproduction and rearing of juveniles (**Fig.** 28). Because of artificial rearing stock abundance decline in the Caspian Sea was slowed down. Still the yield of sturgeon family in Russia went down to 1,300 t in 1996 (Magnik and Sharcscopf 1998). Most of the natural reproduction of sturgeon family in the basin of the Caspian Sea belongs to Russia. The reason is that 69% of natural reproduction take place in the rivers of Russia.

Year	Salmon	Sturgeon	Herring	Sprat	Big fish									Grey mullet	Roach	Small fish	Other	All
					zander	bream	sazan	catfish	asp	pike	Black Sea roach	Other	all					
1900	1.1	29.8	73.6		29.1	14.9	23.8	4.3	4.0		0.5	0.01	76.6		119.7			**300.0**
1905	0.3	27.2	102.0		21.8	24.5	11.1	8.0	1.5		0.6	-	67.5		184.7			**381.7**
1910	0.6	23.1	168.5		48.2	8.5	13.9	5.7	1.7		1.2	-	79.2		175.6			**447.0**
1913	0.8	28.5	238.2		42.3	10.6	28.1	11.2	3.3		0.7	0.01	96.2		136.6			**590.3**
1915	0.7	26.9	286.9		14.1	9.6	38.4	11.0	1.5				74.6		157.3			**546.4**
1917	0.2	8.5	319.7		31.6	11.5	63.8	5.8	1.9		-	-	114.6		162.8			**605.8**
1920	0.1	2.9	48.9		8.1	1.9	6.2	0.7	0.7			-	17.6		50.8			**120.3**
1925	0.4	12.1	165.1		45.6	18.6	17.3	2.4	2.8		-	-	86.7		174.5			**438.8**
1930	0.4	13.7	134.1		90.2	25.6	12.9	2.6	3.5		1.3	-	146.1		263.4			**557.7**
1935	1.1	19.3	57.6	4.5	58.6	105.0	16.4	4.9	3.3	1.9	1.4	0.6	192.1		170.1	27.2	2.1	**474.0**
1940	1.1	7.5	136.5	8.9	35.4	62.0	14.8	2.9	1.6	5.0	2.1		123.8	0.1	51.4	17.9	2.3	**349.5**
1945	0.3	3.6	103.5	9.2	32.1	87.7	18.3	1.6		4.3	0.4	0.6	145	0.1	66.5	12.0	1.1	**341.3**
1950	0.4	13.5	56.1	21.7	31.4	75.4	33.8	10.1	2.5	4.0	0.3	1.6	159.1	0.3	59.6	19.9	1.0	**331.6**
1955	0.1	10.5	45.9	133.8	30.0	37.1	21.7	10.0	3.2	11.3	1.2	0.3	114.8	1.6	109.0	38.9	1.4	**456.0**
1960	0.01	10.1	54.9	176.0	14.6	23.3	7.6	5.9	2.3	5.9	0.5	0.1	60.2	0.7	64.1	20.3	0.3	**386.6**
1965		14.9	3.5	343.2	6.8	18.9	4.0	10.0	0.4	5.3	0.1	-	45.5	0.6	18.4	23.8	0.2	**450.1**
1970	0.01	16.1	1.9	423.2	4.0	22.5	5.1	14.5	0.7	7.0	0.02	0.03	53.8	0.6	12.7	22.3	0.2	**530.8**
1975	0.01	23.3	1.6	342.5	4.6	17.7	7.0	15.3	1.0	5.5	0.04	0.02	51.1	0.5	26.2	17.9	0.1	**463.2**
1980	0.02	25.1	1.1	304.8	1.0	4.0	3.8	9.2	0.2	4.7	0.1	0.01	23	0.2	5.8	23.2	0.1	**383.3**
1985	0.03	21.2	3.5	269.4	1.6	8.5	6.7	8.4	0.3	3.6	0.1	0.1	29.3	0.2	8.6	11.7		**343.9**
1990	0.01	13.7	2.3	235.3	4.6	16.9	4.2	10.4	0.3	4.2	0.05	0.1	40.7	0.2	20.8	11.0	0.0	**324.0**
1995	0.05	2.9	1.6	107.9	4.1	25.3	2.6	5.4	0.7	3.7	-	0.1	41.9	0.02	16.2	10.6	0.1	**181.2**
1997	0.02	1.8.	2.3	102.0	4.1	27.5	3.2	8.0	0.7	3.5	-	0.4	47.4	0.02	12.1	12.7	-	**178.3**

Fig. 26. Catch of fish in the Caspian Sea basin, thousand t (by Ivanov V .P. et al. 1999)

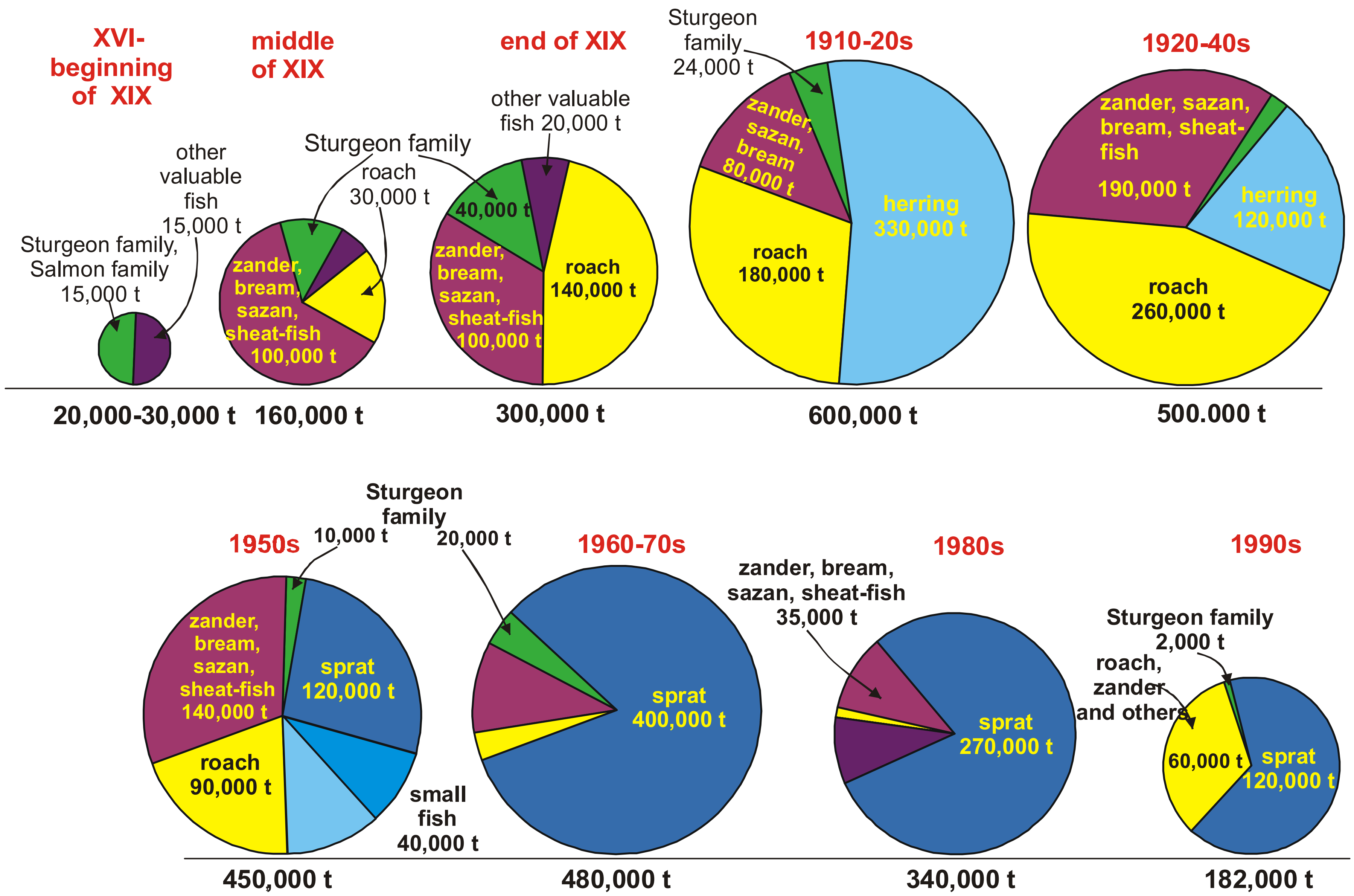


Fig. 27. Dynamics of different fish species catch in the Caspian Sea basin (by Ivanov V. P. et al. 1999.)

The basin of the Caspian Sea is characterized by the diversity of river and semianadromous fishes. In 1900–1910 catches of larger fishes (zander, bream, etc.) exceeded 100,000 t and yield of Caspian roach amounted to 200,000 t. In 1926 yields of larger fish and Caspian roach comprised 110,000 t and 226,000 t. Larger fishes and Caspian roach yields went down in the 1970–80s because the conditions were unfavorable for reproduction. The most significant decline in the Northern Caspian productivity occurred in the 1960s as the result of the Volga river runoff regulation and in the 1930s and 70s because of the sharp lowering of the sea level (Vlasenko 1997). In the 1990s yield of river fishes and Caspian roach never exceeded 30,000 and 25,000 t respectively, i.e. a 4–10 fold reduction in the yields as compared to the yields in the early years of the century.

The Baltic Sea. Cod stocks continuously decreased from 391,000 to 40,000 t over the period 1984–1993. For several years Russia has been calling for a moratorium on fishing cod since the development of fishery threatens the very existence of the stock. Kilka catches at the beginning of the 90s range from 20,000 to 50,000 t. Total catches in the Caspian Sea are 4–5 times less than they used to be (Karaseva 1997).

The White Sea. The output of the White Sea is comparatively small. Its benthos is extremely poor. The total catch in the sea ranges from 30,000–40,000 t in the 19th century, 5,000–15,000 t in 1940–60s. In the 1990s catch comprised 2,000–4,000 t.

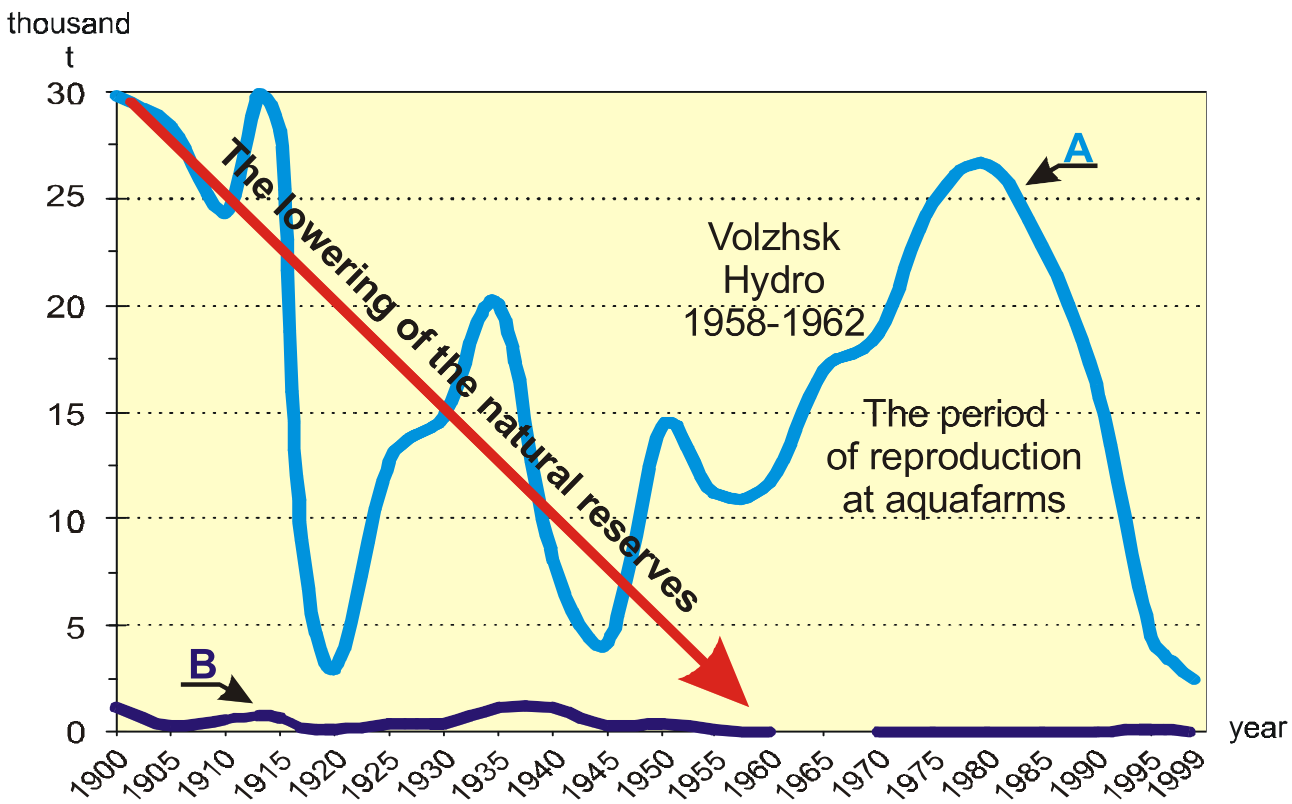


Fig. 28. Catches of sturgeon family (A) and salmon family (B) in the Caspian Sea basin (by materials of Ivanov V. P. et al. 1999)

A regular fishery in the White Sea has been carried out since the 12th century. The commercial stocks include salmon, navaga, humpback salmon, white fishes, herring, cod and arctic flounder. The most important marketable species are salmon, Arctic salmon, herring and navaga. Peak catches of Arctic salmon never exceeded 200,000–400,000 t. Catches of all other species are not significant and their catches are not limited. Polar cod migrates to the White Sea during the periods of cooling.

Herring. Before the middle of the 19th century catch comprised 32,000 t, during the 1860–70s catches were about 10,000 t. In 1928 the catches declined to 8,200 t per year, and in 1998 the catch was only 650 t.

Cod. Normally it does not exceed 8% of total catch. Over the period of 1936–51, catches ranged from 0.93 t (1948) to 142.7 (1940). Catches of cod in Kandalaksha Bay varied between 0.9 to 143 t over the period 1951–1963. According to the Fishery Committee of Karelia, the catches in 1951–1987 ranged from 0 (1963, 1980, 1982) to 315 t (1957).

Navaga. The lowest catches of navaga (580–670 t) were registered at the end of the 1930s. Commercial stock biomass in the 1980s was 5,000–5,500 t. Nowadays maximum catch is 1,000 t (**Fig.** 29).

The Barents Sea is one of the world's richest seas. In the late 1970s, yield of sea products in the Barents Sea amounted to 4.5 mln t annually. Only cod catches were at the level of 1.2–1.4 mln t (**Fig.** 30, 31). By the end of the 1980s fishing of herring, capelin and polar cod was stopped. At this time the total catch was 300,000 t. By the beginning of the 1990s, the cod yield went down to 210,000 t and parental stock biomass was at its lowest since introduction of fishery into the area (*Atlantic cod: biology, ecology, fishery 1996. Edited by G.G. Matishov, Rodin*).

Period	Navaga	Herring	Salmon	Other marketable fish	Total catch
1956-1960	1232	2190	499	1040	4961
1961-1965	1280	2192	331	506	4309
1966-1970	1360	583	285	718	2946
1971-1975	1645	750	394	826	3615
1976-1980	1199	1285	342	357	3183
1971	1317	742	239	237	3535
1982	1448	1005	230	407	3090
1983	2479	1032	322	637	4470
1984	2190	1046	329	246	3811
1985	2257	1453	382	210	4302
1986	1566	1858	332	214	3970
1987	2138	1900	344	190	4572

Fig. 29. Annual average catch of fish in the White Sea (t)

By the beginning of 1995, when brood and commercial stocks of cod were 1.9 and 0.8 mln t respectively, it was possible to recommend sustainable harvest of 740,000 t. Nevertheless, optimistic forecasts have failed to materialize and quotas have been constantly reduced over the last three years (1999–520,000 t of cod).

Let us describe dynamics of decrease in catches of other marketable species without going into further detail. Yield of Atlantic cod reached its peak of 2 mln t in the 1960s. The stock became of no commercial interest in the 1970–80s when catches comprised nearly 10 fold less historical values (**Fig.** 32). It is only in the mid 90s when the commercial stock was restored. Total catch of herring in 1997 comprised 1.3 mln t, but it is hard to say how resistant to the growing fishery stress it will be. Yields are influenced by annual stock abundance fluctuations which are characteristic of most stocks in the Barents Sea. And even here we find a long term tendency to decrease. E.g. Ocean perch catch 270,000 t in 1976 and 14,000 t in 1995, black halibut catch 76,000 t in 1971 and 12,000 t nowadays (Shleinyk 1996).

Still the most drastic changes happened to capelin. General stock size of 4 to 7 mln t and brood stock of 1 to 4 mln t were providing good yields in the 1970s. The peak catch of capelin comprising 3 mln t was recorded in 1977 (**Fig.** 33). At the beginning of the 1980s, the average catch was approximately 2 mln t. This resulted in reduction of general and brood stocks. In 1986, commercial fishing of capelin was banned. Capelin and northern shrimp are not only important fishery objects, but also constitute the main part of cod diet (and of other benthic fish), seabirds and sea mammals. That is why their abundance is essential for the Barents Sea ecosystem.

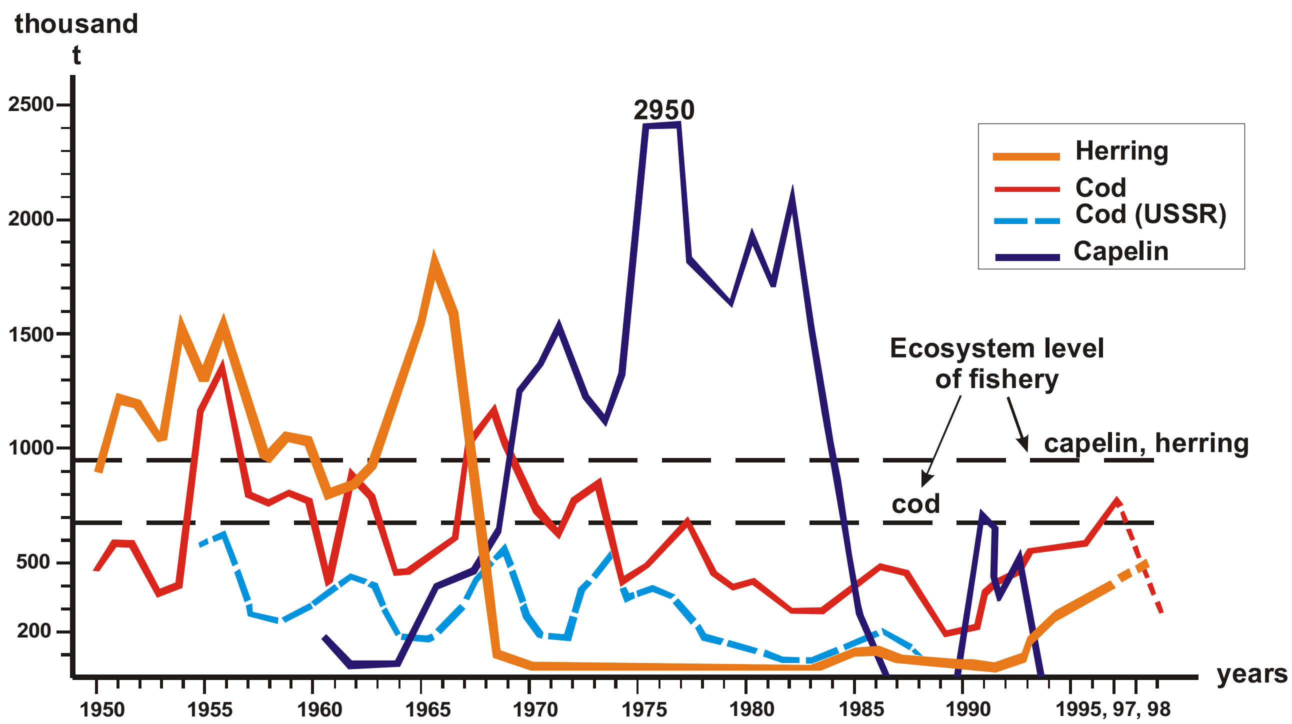


Fig. 30. Fluctuations of the world catch of some commercial fish species (the Barents and the Norwegian seas) by ICES data

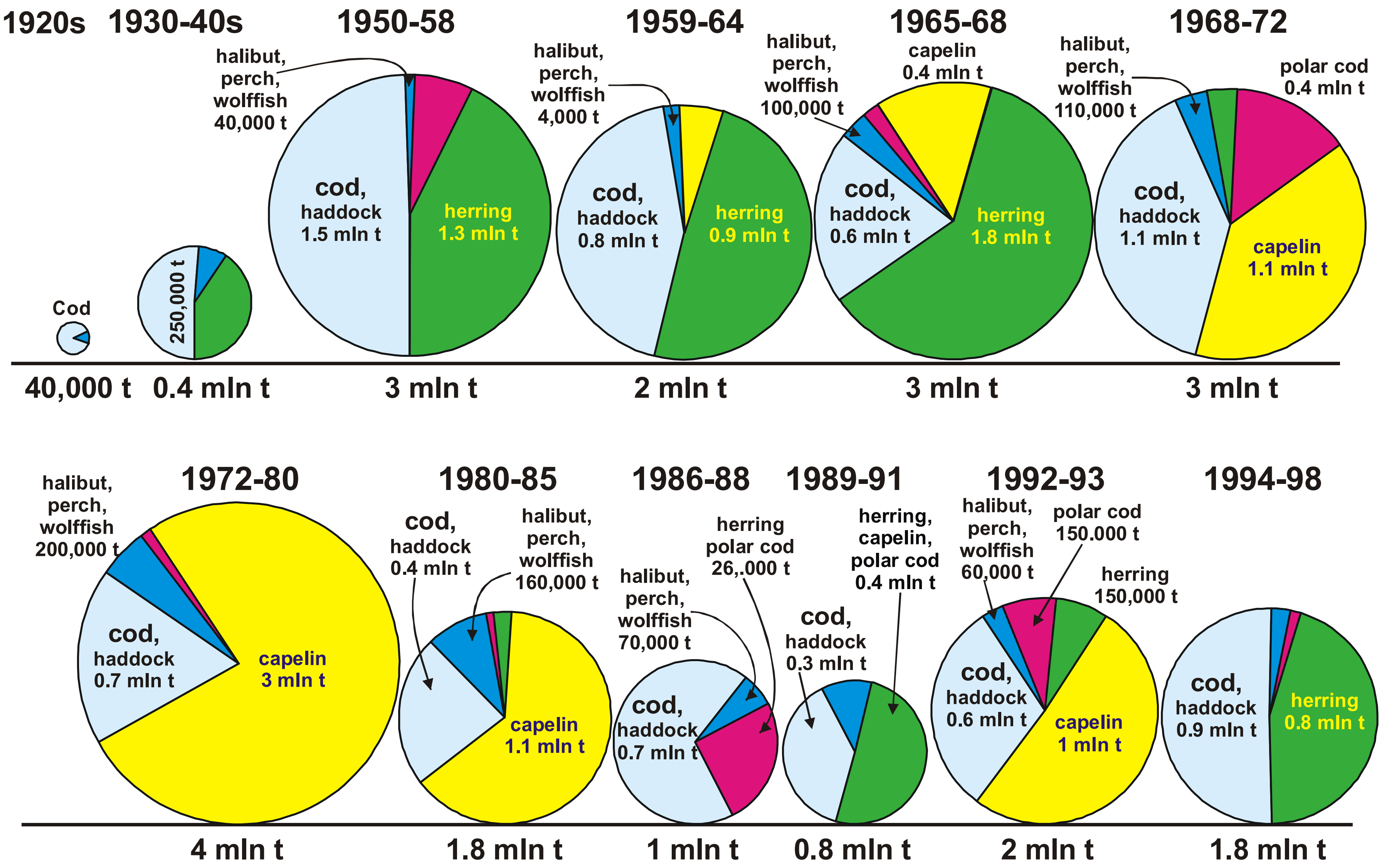


Fig. 31. Dynamics of catch of different fish species in the Barents Sea (by PINRO *and* ICES *and other materials)*

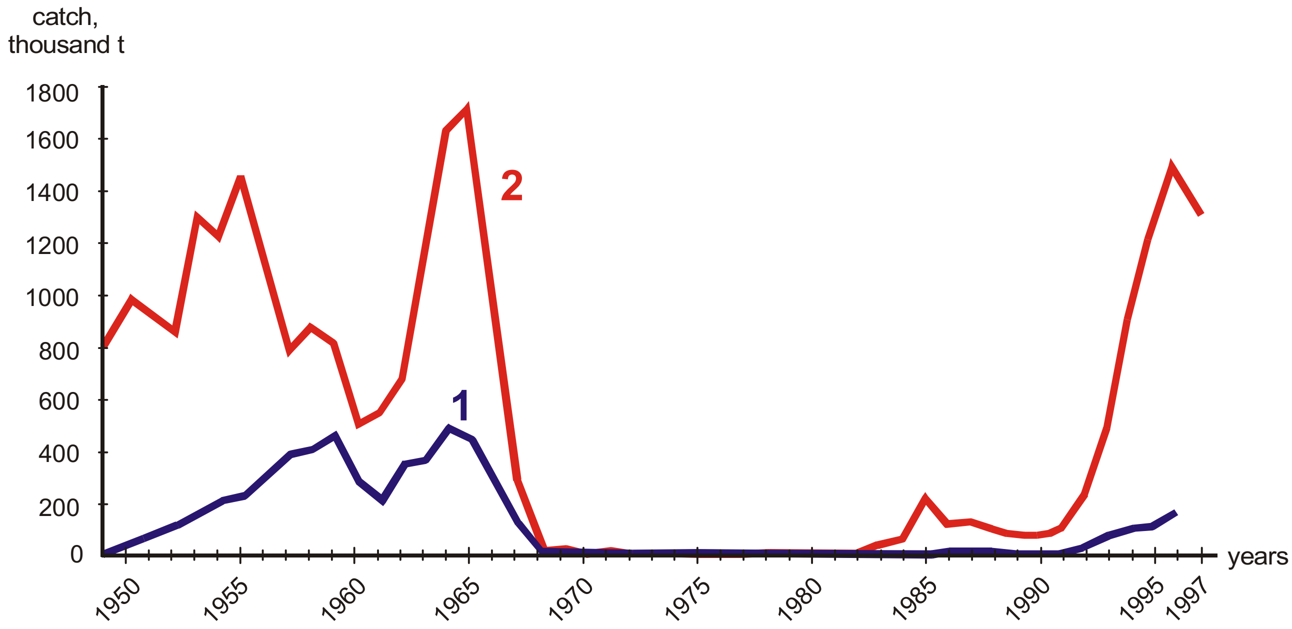


Fig. 32. Catch of herring by Russian fisheries (1) and by fisheries around the world (2) (by PINRO data, 1998)

Year	Total catch							
	Spring				Autumn			All
	Russia	Norway	Other	All	Russia	Norway	All	
1976	228	1252	—	1480	368	739	1107	2587
1977	317	1441	2	1760	504	722	1227	2987
1978	429	784	25	1237	318	360	678	1915
1979	342	539	5	886	326	570	896	1783
1980	253	539	9	801	388	459	847	1648
1981	429	784	28	1240	292	454	746	1986
1982	260	568	5	833	336	591	927	1760
1983	373	751	36	1161	439	758	1197	2358
1984	257	330	42	629	368	481	849	1478
1985	234	340	17	590	164	113	278	868
1986	51	72	—	123	0	0	0	123
1987	Fishing banned							
1988	—"—							
1989	—"—							
1990	—"—							
1991	159	528	20	707	195	31	226	933
1992	247	620	24	891	159	73	232	1123
1993	170	402	14	586	0	0	0	586
1994								
1995	Fishing banned							
1996	—"—							
1997	—"—							

* Mainly the Faeroes Islands

*Fig. 33. Total catch of the Barents Sea capelin by the Russian, Norwegian and other fisheries in spring and autumn 1976-1997, thousand t (*by ICES data*)*

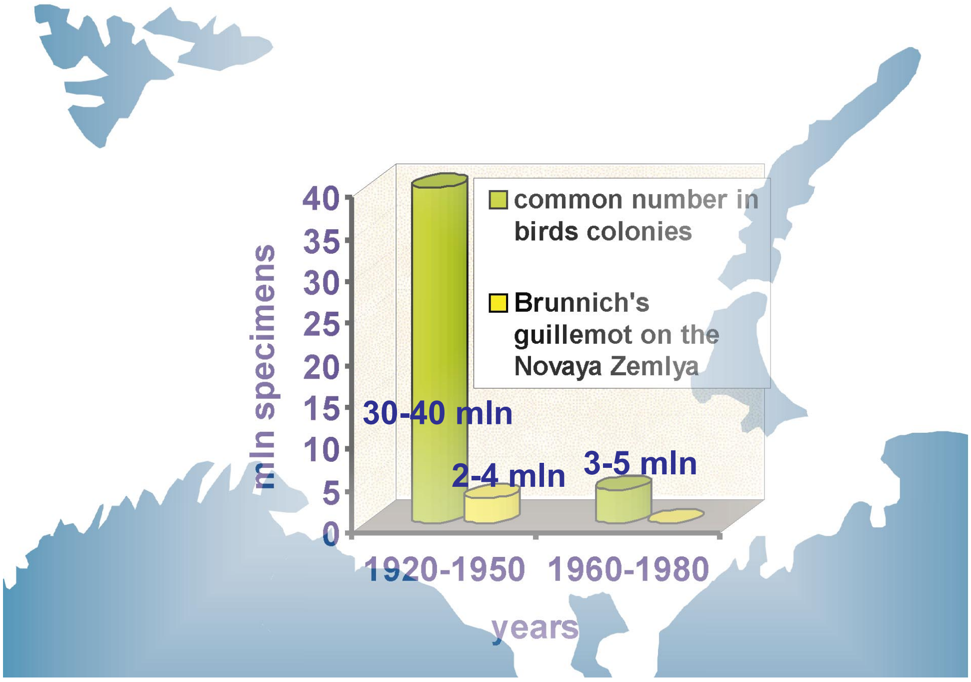


Fig. 34. Dynamics of birds abundance in the Barents Sea in the 20th century (by published data)

In terms of commercial value, Atlantic salmon is top of the list in the North, enjoying the same status as the sturgeon family in the Southern seas. Over 2,000 t of salmon were captured last century in the basins of the Barents and the White seas annually, i.e. 10 times as much as at the end of the 20th century (Alekseev and Ponomarenko 1997). Now, the arctic salmon stock together with Pechora salmon stock is on the verge of extinction and urgent steps should be taken to restore them.

Commercially valuable species of benthic invertebrates (Polar shrimp, Iceland scallop) were under heavy fishery stress. Catch of scallop alone in 1990–1997 in the South-East of the Barents Sea grew from 2,000 to 14,000 t per year. Nowadays stock of this mollusk is decreasing and restoration of its abundance might take 10–15 years.

Intensive extraction of Polar shrimp in the Barents Sea was started at the beginning of the1980s. In 1984–1985, annual average catch comprised over 120,000 t. Later catches were getting poorer until they hit the bottom with less than 24,000 t in 1995.

Large scale use of trawling equipment meant for benthic fishes had a most destructive effect upon benthos. These trawls are primarily used for fishing Arctic cod and Azov goby. Catches of goby in the 60s reached 92,000 t annually (Spivak et al. 1995). It is easy to imagine how deep the «disturbance» of the benthic community was in the Azov Sea with its shallow waters (5–12 meters) and relatively small area.

We suppose, that all the above mentioned examples are convincing enough to show the general trend of (with some rare exceptions) decrease in stock abundance and yields of nearly all marketable species at the close of the 20th century.

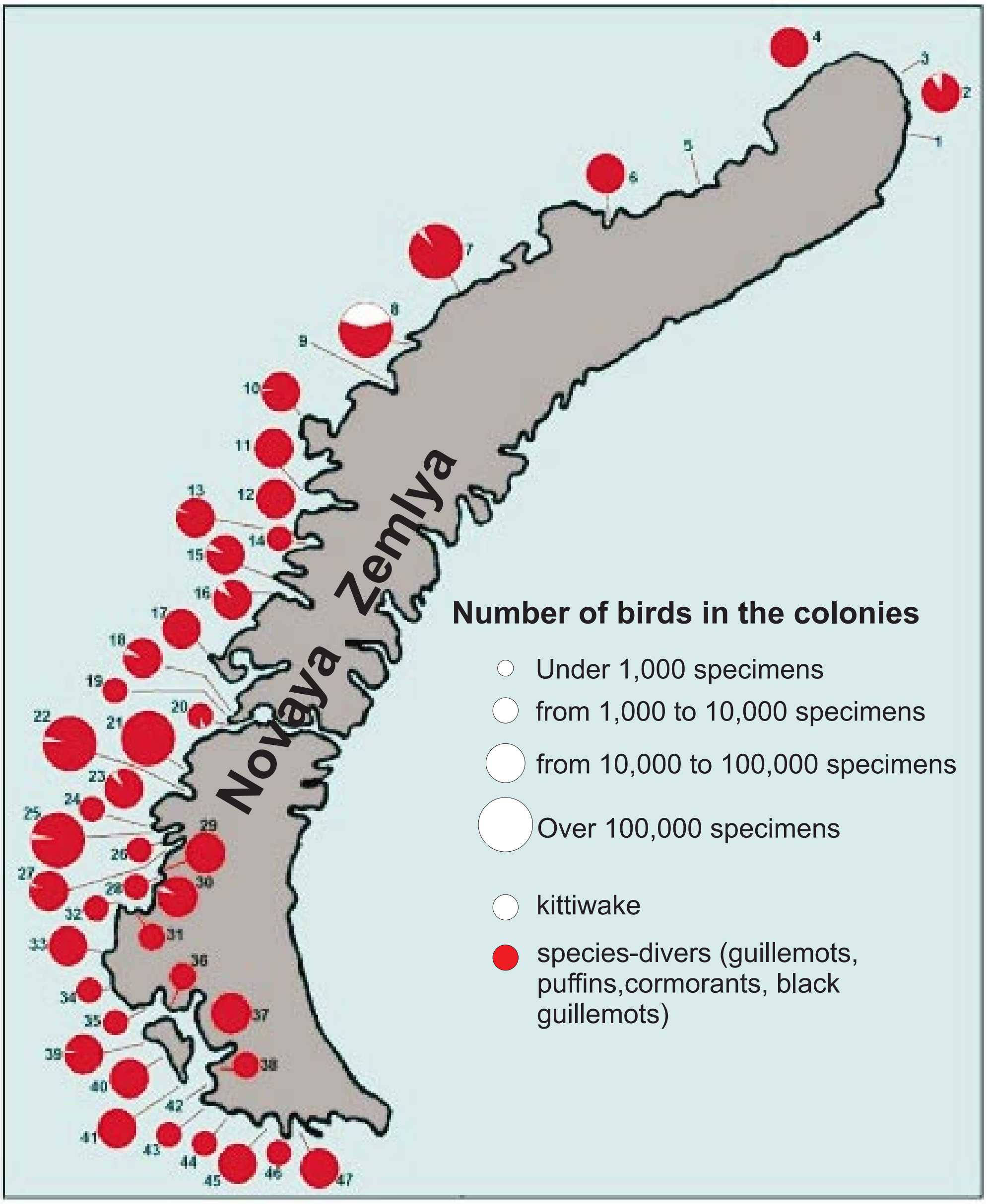


Fig. 35. Distribution and abundance of sea birds in the Novaya Zemlya colonies (by Uspensky 1956, Golovkin 1972)

1.Cape Bismark; 2. Island Gemserk; 3. Bay of Natalia; 4. Oranskie Islands; 5. The Great Ice (Ledyanoy) Bay; 6. Russian Harbor; 7. Archangelskaya Bay; 8. Vilkitsky Bay; 9. Nordensheld Bay; 10. Sadovsky Bay; 11 Mashigin Inlet; 12. Cape Shants; 13.Cape Chernitsky; 14. Severnaya (Northern) Sulmeneva Inlet; 15. Cape Prokofiev; 16. Cape Lavrov; 17. Sykhoy Nos; 18. Mitushev island 19; Cape Serebryany (Silver); 20. Matochkin Shar; 21. Grubovaya Inlet; 22. Bezymyannaya Inlet; 23. Peninsula to the south of the Bezymyannaya Inlet; 24. Cape Britvin; 25. Pukhovy Bay; 26. Srednyaya (Middle) Inlet; 27. Kuvshin (Jug) Island; 28. Malaya Karmakulskaya Inlet; 29. Na Vilakh (Karmakusky Island); 30. Karmakulsky island ("Domashny (Domestic) bazar"); 31. Obsedia Inlet; 32. Mouth of the Talbey Yaga river; 33. Mouth of the Sauchikha river; 34. Cape Ne Bazar; 35. Cape Lilie; 36. Cape Morozov; 37. Island Yartsev; 38. Cape Valkovo; 39. Cape Shadrovsky; 40. Cape Lebediny; 41. Island Mezhdusharsky; 42. Cape Muchnoy; 43. Selesnev Inlet (northern part); 44. Selesnev Inlet (southern part); 45. In front of the Chernaya Inlet; 46. Chenrnaya Inlet (near the entrance); 47.Sakhanin Inlet

SEABIRDS AND COLONIAL BIRDS

Seabirds owing to their abundance produce the major impact on reservoir ecosystem dynamics. Effects of the impact are best seen in the coastal areas and in the areas adjacent to water fronts. Multimillion seabird populations graze on sea inhabitants (crustaceans, mollusks, fish) thus being the key element of phosphorus cycle. The Barents Sea seabirds population alone in the middle of this century amounted to tens of millions birds (**Fig.** 34, 35). The number of Brunnich's guillemots in fifty colonies at the Novaya Zemlya regardless of other species equaled 2–4 mln (Uspensky 1956).

Eggs, nest-down and meat of some species of seabirds were commercially exploited (eider, guillemot, etc). Overexploitation resulted in sharp decrease in the abundance and patrols were set up. But it was food shortage caused by overexploitation of stocks of the marketable fishes in the 1960–80s that led to drastic decrease in the density of bird colonies in the European seas. Degradation of ornitofauna was marked by mass die off of juvenile birds at the wintering sites, reproductive capacity reduction of glaucous gulls, eiders an other birds (**Fig.** 36).

The position of birds in ecological hierarchy is characterized by the specific part they take in helminthes cycle. Parasites are a stabilizer on account of their influence on the host population dynamics. Bird helminthes larvae constitute a significant (if not prevailing) segment of marine invertebrates and coastline area bound fishes parasitofauna (Krasnov et al. 1995). A sharp decrease in bird abundance disrupts parasites life cycle thus reducing coastal ecosystems resistance to outside influence.

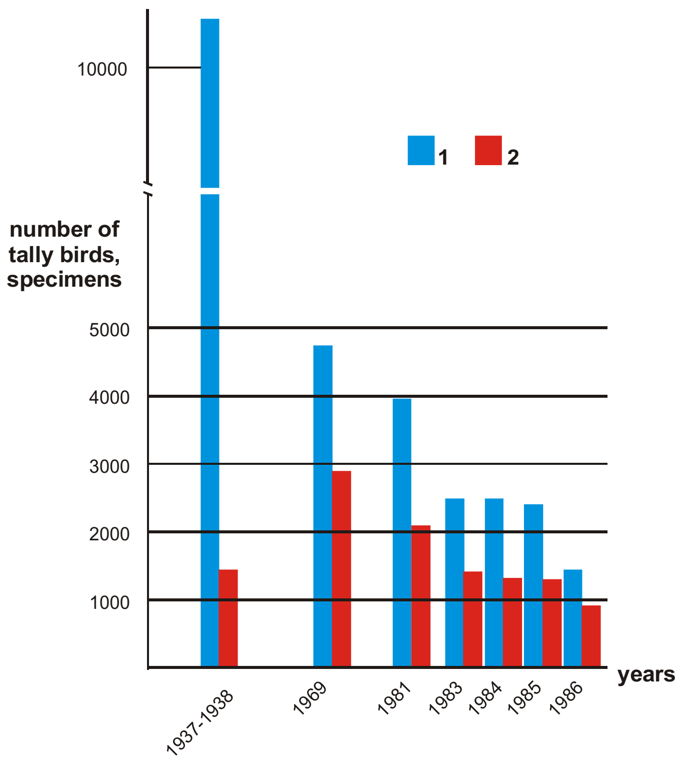


Fig. 36. Dynamics of abundance of the great black-backed (2) and herring gulls (1) on the Seven Islands in 1963-1985 (Krasnov et al.,1995)

Natural lifecycle of birds provides rich supply of carbon- and phosphorous containing substances to pelagic waters and coastal areas, which are necessary for feeding of phyto- and zooplankton, macrophytes and littoral benthos. All these contribute to high bioproductivity of seas (Krasnov et al. 1995). The weakness of ornitofauna, as a matter of fact, has negative impact on reservoir bioproductivity.

CURRENT CHANGES OF THE POPULATION STRUCTURE AND SPECIES COMPOSITION

It is quite natural, that in the course of time the structure of fauna and species composition may change. Reasons might be numerous and introduction (casual or artificial) is only one of them. This implies that diverse biological consequences of natural or artificial substitution of vanishing or weak elements of marine ecosystems deserve special consideration. These continuous processes affect all trophic levels from whales, walruses, dolphins to various species of plankton. First of all we have to consider such processes as

- quantitative outbursts of scarce species
- unintentional introduction of alien species (alien invasion)
- planned introduction of species typical for other seas (introduction).

QUANTITATIVE OUTBURSTS OF SCARCE SPECIES

Processes in the Black and Azov seas basin give a good idea of the nature of the process (**Fig.** 37). Bream, zander and silver porgy (*Carassius auratus gibelio*) are the three most important marketable fishes of the Azov basin. The share of silver porgy in the yield pattern over the period from 1983 to 1994, by Azovrybvod, increased from 1.7% to 30.7%, in 1996 this figure was 20.8%. Annual catch of this species varied from 100 to 1,500 t (Abramenko 1998). In some cases catches amounted to 50 t per one deployment of gear.

There is a number of interdependent and interacting variables that explain this phenomena of outburst, stabilization of abundance at the high level and expansion of silver porgy. Initially this species migrated to the Azov Sea from the ponds into which it had been introduced by aquafarmers.

Alteration of hydrological and hydrochemical cycle of ecosystems in the Azov-Don and the Azov-Kuban basins in the 1950–1970s led to transformation of genetic structure of porgy population in the estuaries of the Don and Kuban rivers from unisexual-bisexual structure to predominating bisexual structure. A unisexual gynogenetic model using male sperm of closely related valuable species of Cyprinidae family (carp, bream, sea-roach) for reproduction was absolutely dominating until the end of the 1970s (Abramenko and Kravtchenko 1998). Later the mouth and the estuarine part of the Don River became a home base for expansion of this unpretentious fish in two directions characterized by formation of river, pond and sea populations.

The trend of previously scarce species became clearly distinct in the Barents Sea in the 1980–90s (**Fig.** 37). Populations of *Hyperiid amphipods*, medusas (common jellyfish, *Cyanea arctica*), ctenophora, squids, pearlsides (bathypelagic fish moving in shoals) became very prominent in the ecosystem.

Common jellyfish biomass in the Black Sea over last 30 years increased from 1.38 to 12 g/m^3, its wet weight grew from 670,000 t to 500–600 mln t (it is 300 times as much as the total biomass of all fishes of the sea), occurrence in catches made by trawls with small mesh (meant for adolescent fish) comprises 21 to 89 %. The north-west population of the Black Sea medusa in the middle of the 80s (over 40 mln t) was consuming up to 62% of diurnal forage zooplankton

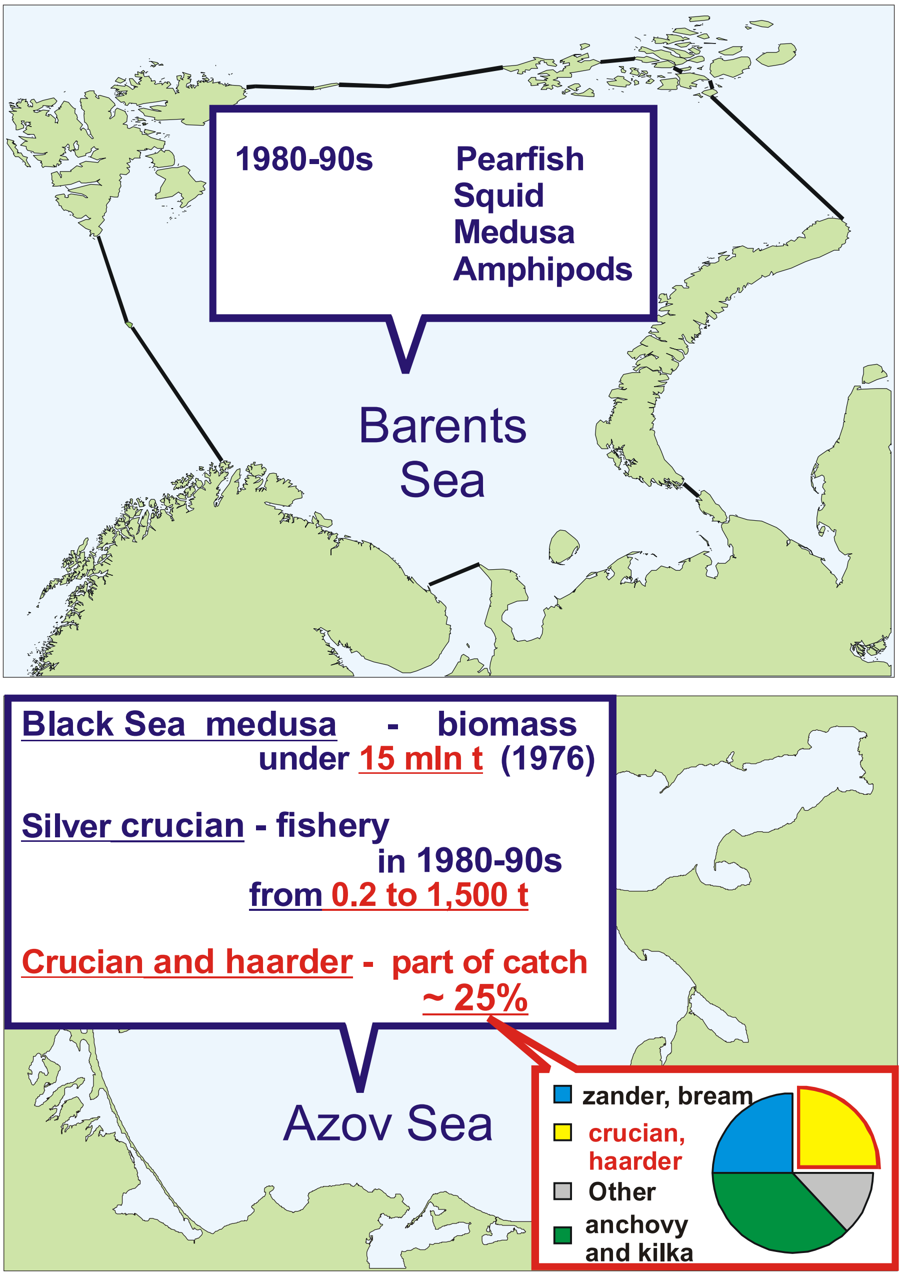


Fig. 37. The outbursts of scarce species in the Barents Sea and Azov Sea (by Timofeev 1996, Abramova 1998, Volovik et al.)

production of the sea on the whole and up to 5–7% of its biomass (Gomoyou and Kuprijanova 1980, Zaitsev and Polyshchuk 1984, Flynt et al. 1989).

Increase of the Azov Sea salinity level in the 1970s triggered reproduction of medusa originating from the Black Sea, which started competition with fishes for zooplankton (**Fig.** 38). In 1976, this population had wet weight of 15 mln t. All this huge medusa biomass was «contaminating» the sea as it was not grazed upon by other hydrobionts.

Year	Medusa	Ctenophora	Year	Medusa	Ctenophora
1974	1.98	-	1986	0.07	-
1975	3.60	-	1987	0.04	-
1976	15.5	-	1988	0.4	0.04
1977	7.3	-	1989	single	32.0
1978	7.0	-	1990	single	20.0
1979	5.9	-	1991	single	30.2
1980	3.9	-	1992	single	15.1
1981	0.4	-	1993	single	21.4
1982	0.3	-	1994	single	21.1
1983	0.23	-	1995	single	18.7
1984	0.013	-	1996	single	22.0
1985	0.10	-			

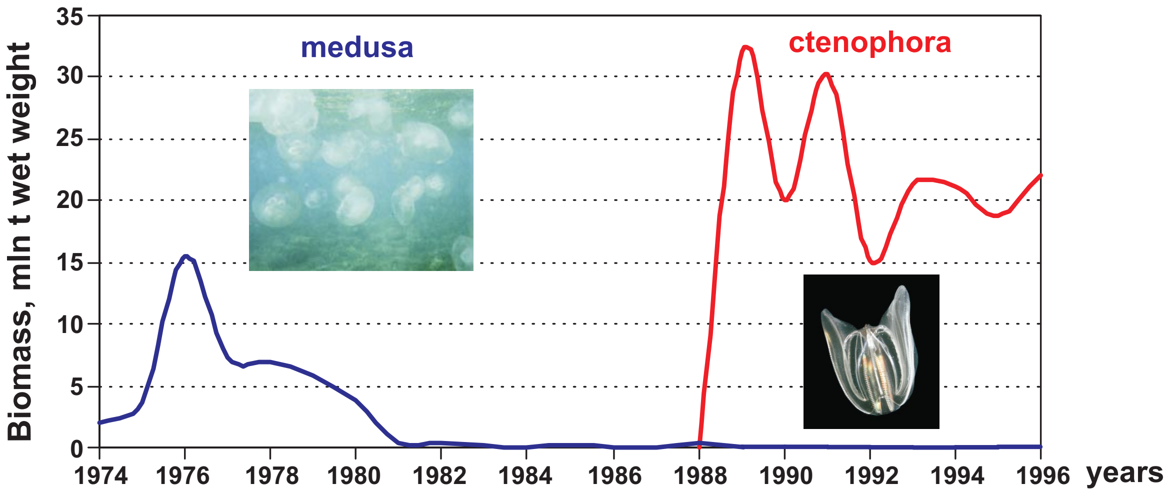


Fig. 38. Dynamics of jelly fish and comb-jelly biomass in the Azov Sea (by Volovik et al. 1998)

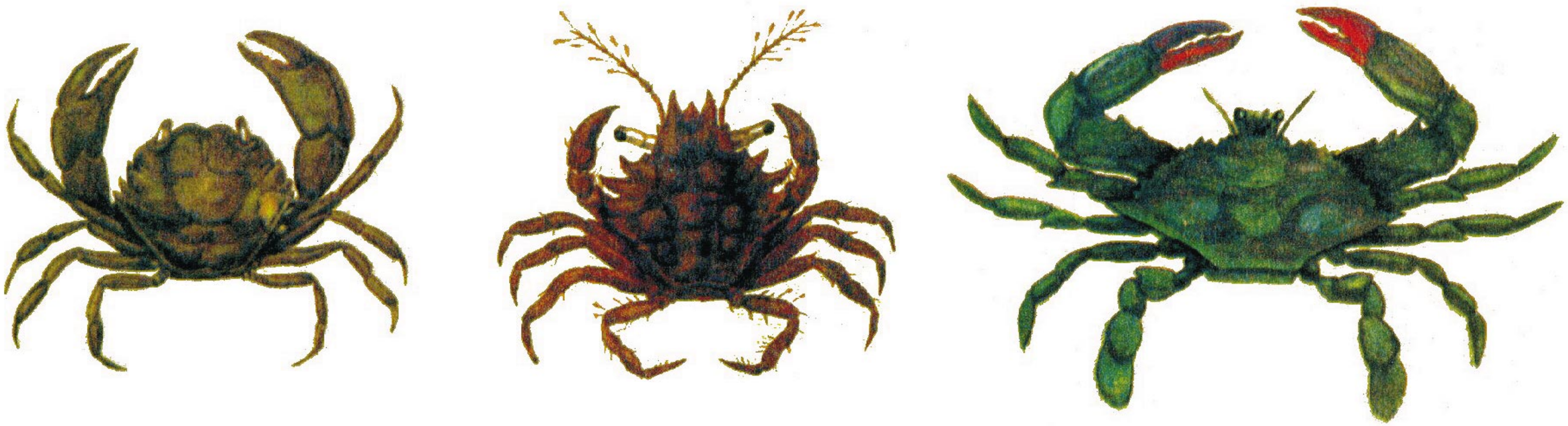
UNINTENTIONAL INTRODUCTION OF ALIEN SPECIES

The problem of introduction of alien species is characteristic of many seas of the World Ocean. Alien species invasion often causes repression of local competitors for food, leads to huge quantitative outbursts both resulting in incalculable economic losses.

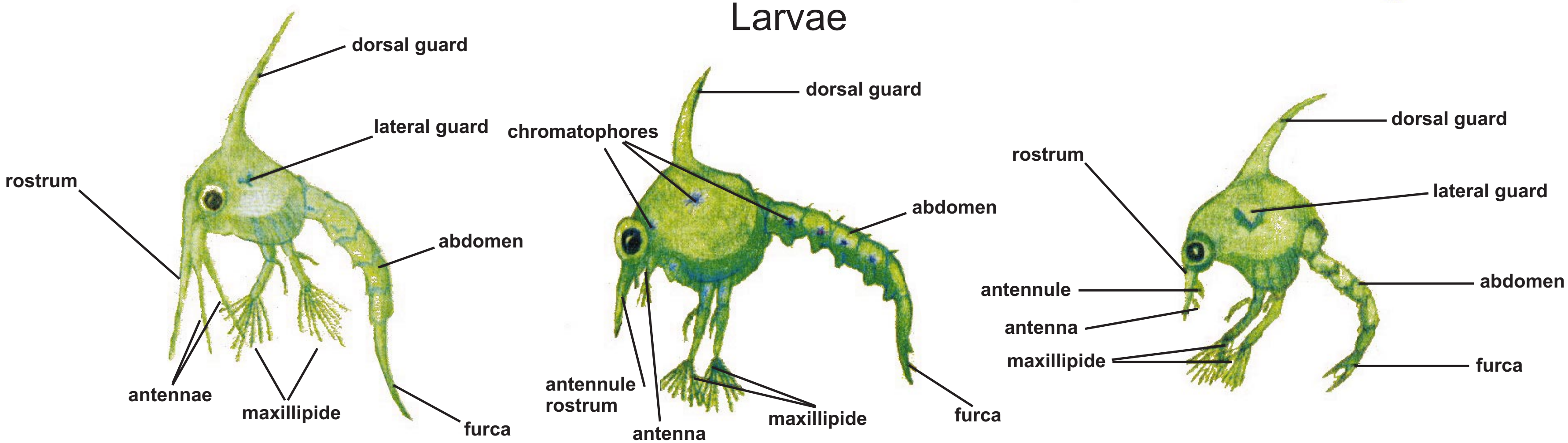
The Black Sea

It is worthwhile to mention three of the casual migrants, crabs *Brachyr* (**Fig.** 39): *Rhithropanopeus harrisii tridentatus*, *Callinectes* and *Sirpus zariquieyi* (Makarov and Murina 1998). *Rhithropanopeus harrisii tridentatus*, a subspecies of American crab (*R. Harrisii*), lives in fresh and brackish waters of the coastal area of the American continent. This crab was traced in the basin of the Black Sea first in the Dnieper and the Don rivers estuaries in 1939 and 1952 respectively. In the course of several years its population expanded to the Azov Sea. This subspecies also migrated to the Caspian Sea via the Volga-Don canal and occupied all vacant positions of upper sublittoral ecosystem.

Adults



Larvae



On the left to the right: the males of holland crab and sirpus, adult female of blue crab

Fig. 39. Crabs introduced to the Black Sea (by Makarov Yu.N., Murina V.V.)

Blue crab is a migrant from the Atlantic coastline area, too. It is very resistant to freshening of water and is often found in estuaries and lagoons, though it can also live in waters with high salinity. Despite its relatively small number in the Black Sea as compared to *Rhithropanopeus harrisii tridentatus*, it has inhabited much vaster area up to the coastline of the Caucasus. Introduction of the above mentioned crabs might have been facilitated by vessels carrying ballast waters containing larvae.

Alien species invasion has become an extremely dangerous phenomenon (**Fig.** 38). One example is introduction of comb jelly in the 1980s (*Mnemiopsis leidyi*), which was brought to the basins of the Black and Azov seas from the eastern coast of the North America with ballast waters (Vinogradov et al. 1989). Outburst of comb jelly in the Black Sea caused decrease in stocks of sardelle, anchovy and some other marketable fishes both as competitor for food and as predator grazing upon their larvae (Volovik et al. 1991). By the end of the 1980s, its biomass approached 1 billion tons (Zaitsev 1998). Ecological influence of *Mnemiopsis leidyi* on marine biota is determined by its enormous abundance of 10–12 kg/m^3 (Vinogradov et al. 1989). During the period of intensive development its diurnal consumption rate is 7% of actual biomass and over 50% of diurnal zooplankton production.

Mnemiopsis leidyi are both food competitor of fishes grazing on plankton and their immediate predator. This is the explanation of sharp decrease in zooplankton and ichthyoplankton biomass which fishes were grazing upon at the end of the 1980s. During 1989–1990 yields of the Black Sea most popular marketable fish, anchovy, reduced dramatically. At that period, yields of fisheries based in the Black Sea states fell from 650,000 to 90,000 t (Zaitsev et al. 1998).

The Azov Sea

Copepods were dominating zooplankton communities before *Mnemiopsis leidyi* invasion in the Azov Sea (55% of biomass). Rotifiers, cladocerans, temporary plankters comprised only 15–27% of total biomass (**Fig.** 38). As practically all groups of the Azov Sea plankton were food objects for *Mnemiopsis leidyi*, zooplankton community species, age and trophic structures were altered dramatically (Volovik et al. 1997). *Mnemiopsis leidyi* competes with mass pelagic fishes (sardelle and anchovy) for forage by using 80% of zooplankton production. The remaining biomass of forage zooplankton in summer time comprised before the invasion of *Mnemiopsis leidyi* 250–300 mg/m^3 and decreased recently by several orders of magnitude (Lutz et al. 1997). *Mnemiopsis leidyi* increase rapidly (in 1–2 months) during spring and the beginning of summer annually developing gigantic biomass (15–30 mln t of wet weight) (Volovik et al. 1996). *Mnemiopsis leidyi* invasion related losses of sardelle and anchovy yields in the Azov Sea estimated as 100,000–110,000 t annually. Thus introduction of only one new ecosystem element caused changes not only on the local, but on the regional level of the Azov-Black sea basin and altered the system lifecycle.

The Azov Sea ecosystem is dominated by bivalve mollusks. Associations of *Cerastoderma* and *Arba* are main components of benthos communities. They take a really important part in the cycle of matter as main food objects for sturgeon and other benthophages. Numerous newcomers from ocean basins participate in forming shelf associations of *Bivalvia*, which is the case with bivalve mollusk *Anadara sp.* invasion to the Azov Sea (Tchikhatchev et al. 1998). Colonies of *Anadara* in the south of the Azov Sea are connected with biocenosis of *Cerastoderma* *lamarcki* and *Abra ovata*. Over the short period 1989–1992, its average biomass grew from 0.5 g/m^2 to 4.2 g/m^2, and in some areas its density equaled to 32–198 g/m^2 with number up to 10 specimens per 1 m^2. It is obvious, that depth 10–11 m, salinity 10.2–12 ‰, oozy bottom with inclusions of sand or gapers are favorable for expansion of these mollusks.

Stone morocco originating from Far East rivers can be regarded as the case of alien species introduction. The fish was brought to aquafarms of the Don River basin as a result of poor control at the transportation stage over introduction of silver carp, white and black amur. According to *Azov Fishery scientific-research institute* data silver carp became wide spread by the end of the 1980s and nowadays it is observed in Taganrog Bay (Nadtoka and Abramenko 1998). The danger of introduction of this fish is in its facultative parasitism, which finds its manifestation in grazing upon dermal and muscle tissues of commercial silver carps, bream and zander juveniles.

As active planktivore it may become a dangerous competitor for juveniles of carp family during its lifecycle occupying the same positions of biotope in natural reservoirs. Statistical analysis of the data has proven alimentary preference of stone morocco towards larvae of carp family and porgy family. Formation of stable stone morocco populations under favorable conditions of Taganrog Bay may become a prelude to its undesirable penetration to reservoirs of Azov-Don and Azov-Kuban basins.

The Caspian Sea

The danger of *Mnemiopsis leidyi* penetration into the Caspian Sea is present as ships are a good medium of fauna and flora exchange via Volga-Don canal. This is the case of diatomaceous algae *Ectocarpus caspicus* (Caspian endemic) invasion into the Black Sea and vice versa penetration of *Rhizosolenia calcaravis* from the Black Sea into the Caspian Sea where this species became dominant.

Nearly all species introduced to the Caspian Sea are characterized by outbursts of abundance in the years immediately following their settling down. Thus *Rhizosolenia calcaravis* in several years after appearance comprised $^3/_4$ of total plankton biomass and balanus comprised 2 mln t. The outbursts were followed by decrease in aliens number and consequent stabilization of their abundance. Nevertheless, invaders are dominant and the most abundant populations in the Caspian Sea (Zenkevitch and Zevina 1969). Phytoplankton is dominated by *Rhizosolenia calcaravis*, which often comprises more than 50% of its total biomass. Zooplankton is presented mostly by medusa *Blakfordia* and to a greater degree by larvae of *Balanus*, *Mitilaster*, *Syndesmia*, *Nereisa*. It is possible to point out that alien biomass exceeds aborigine biomass. Occasionally introduced buffalo occupied the ecological niche formerly occupied by bream, zander and other benthophages in the Volga river delta.

The Baltic Sea

A representative of Caspian zooplankton the predatory *Cercopagis penqoi* has been increasingly frequently detected in the Bay of Finland of the Baltic Sea beginning from 1992. The reason for this appearance is transfer of eggs resistant to unfavorable environment with ballast waters of vessels (Avinsky 1997). Concentration of this small animal (approximately 1 cm) may reach 300 specimen per m^3 . *Cercopagis penqoi* heavily competes with planktivore for food while it is inedible for fish owing to peculiarities of its morphological structure. The increase of *Cercopagis penqoi* trend leaves little chance to avoid consequences similar to that caused by invasion of the Black Sea by *Mnemiopsis leidyi.* This kind of situation may be expected in other seas of Russia.

The Barents Sea

In May and November of 1996, crab *Chionnoecetes opilio* was first detected in the south-east of the Barents Sea close to Gusinaya bank. This marketable species is wide spread in North Atlantic and North Pacific water areas at depth of 20–500 m. Casual drift of larvae or their transportation with ballast waters is supposed to be one of the possible ways of introduction of *Mnemiopsis leidyi* to the Barents Sea shelf (Kuzmin et al. 1998).

Descriptions of a number of exotic representatives of plankton, benthos and fish are given above. However newcomers are found among ornitofauna as well. According to observations of Kandalaksha State Reserve (Y.V. Krasnov, personal message), two new species of seabirds (gannet, great skua) settled in the Barents Sea region since the end of the 1940s (**Fig.** 40).These birds started colonization of islands and coastlines of Murman in the 1980–90s. The studies proved that colonies comprised birds migrated from Mid Atlantic areas where their food basis had been completely altered by heavy fishing. Increase in fishery waste and decrease in abundance of predatory fishes, alongside with stock growth of such marketable fish of secondary importance as gerbil, facilitated outburst of gannet and great skua populations. After that these birds started formation of new colonies along the Kola peninsula coast.

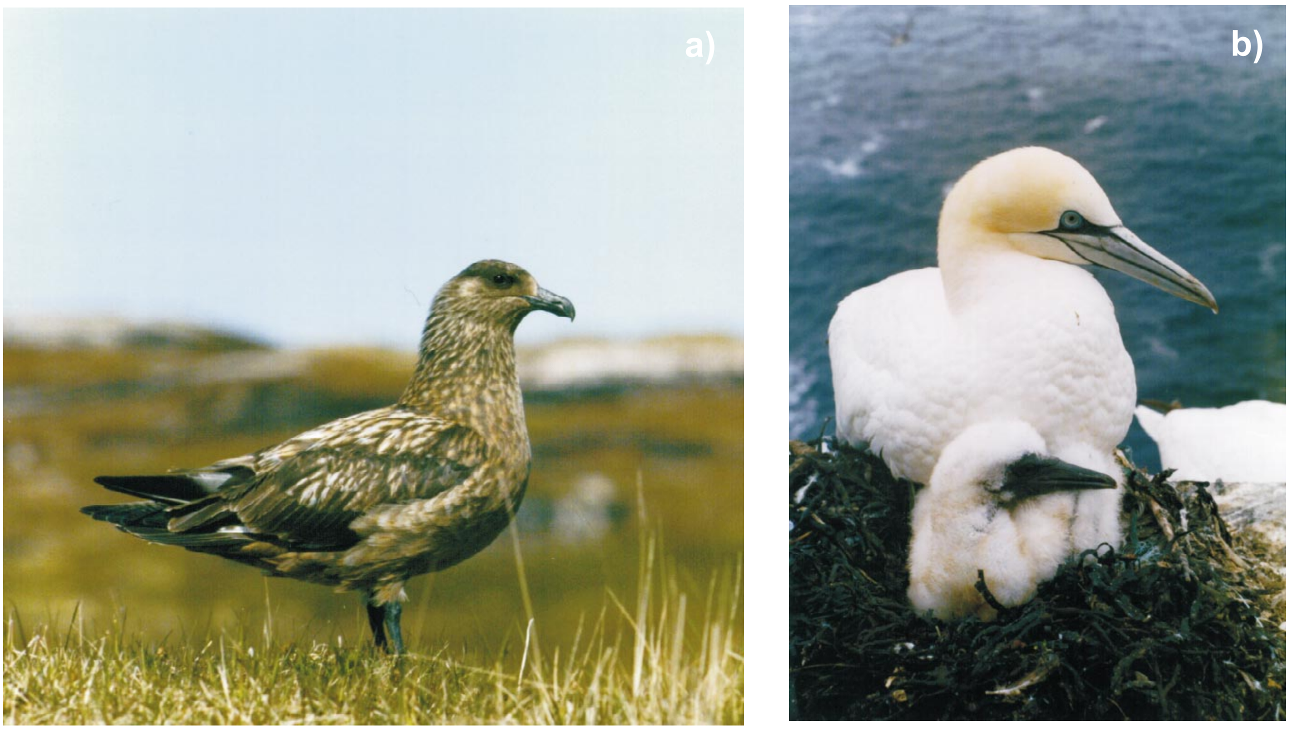


Fig. 40. The North Atlantic introducers into the Barents Sea (Photo by doctor of biological sciences Yu. N. Krasnov) a) great skua;b) garnet

PLANNED INTRODUCTION OF NEW SPECIES FROM OTHER AREAS

It is no accident that new marketable species of fauna from Far East and North America in the 1950–80s were introduced to balance the decrease of bioproductivity in the above mentioned marine ecosystems. 5–12 species were subject to introduction depending on the basin. Commercial and ecological consequences of these demanding and ambitious projects are disputable. There are, however, examples of successful acclimatization (**Fig.** 41). King crab has been successfully introduced to the Barents Sea. Its introduction started in 1961 and since then its habitat has extended to the southern coastline of Norway. King crab experimental extraction has already been launched (up to 40,000 specimens annually). King crab stock reproductive capacity in the Barents Sea according to a 1995 estimate comprises 23.7 billion eggs (**Fig.** 42,43). Total and marketable stock of king crab in the Barents Sea in 1997 comprised 510,000 and 426,000 specimens respectively (Kuzmin et al. 1998b).

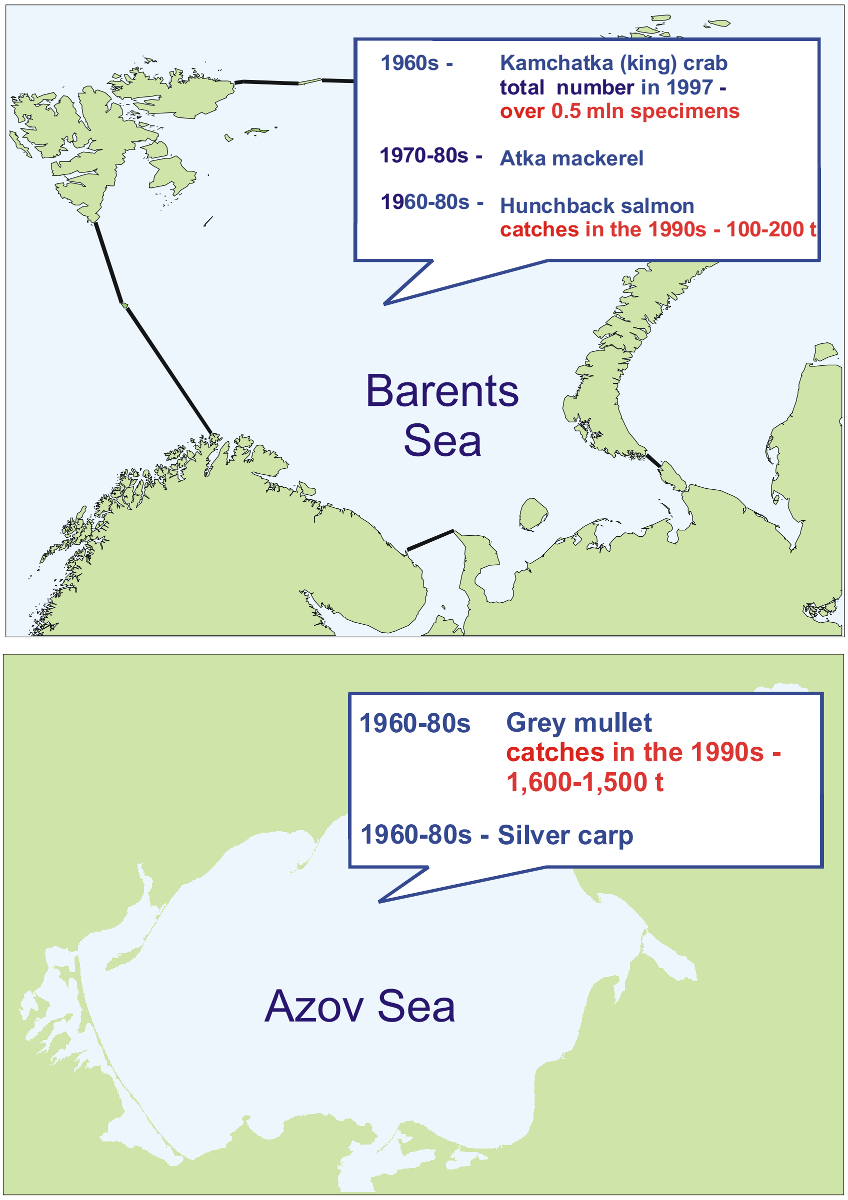


Fig. 41. Introduction of different fauna species

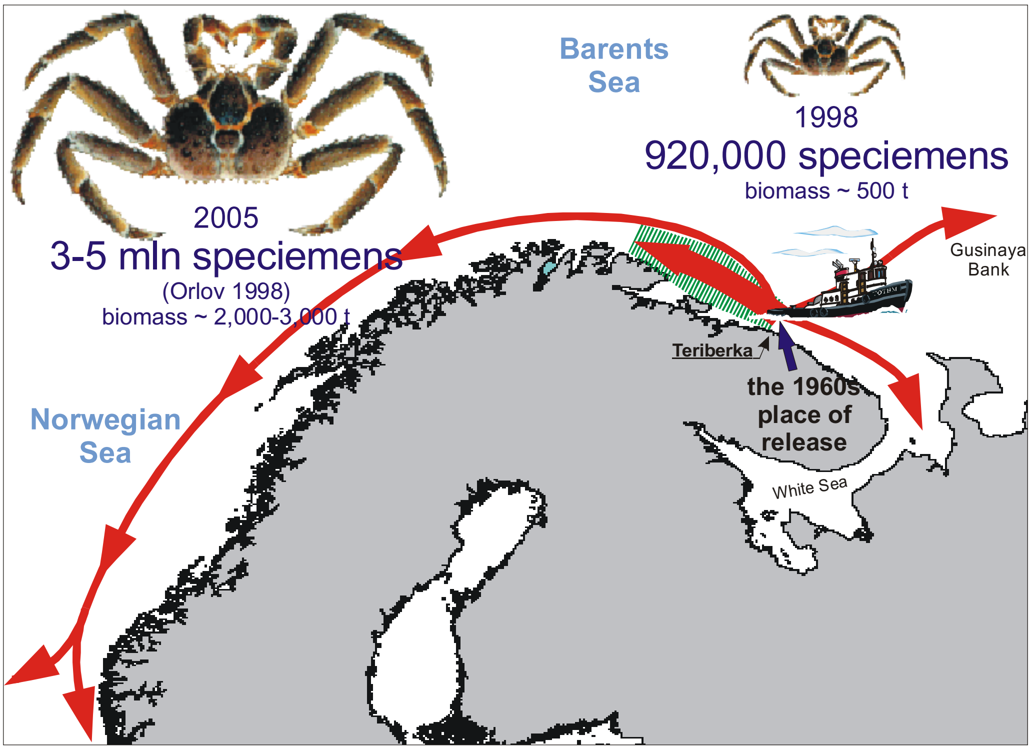


Fig. 42. Settlement of the Kamchatka crab (acclimatized in the Barents Sea) (by the data of PINRO, VNIRO)

Mullets in the Black and Azov seas had lost their commercial value by the 1960s and search for their substitutes began. Nowadays mullets of the Black and the Azov seas are represented by small stocks of local species (gray mullet, golden mullet and leaping gray mullet).

Silver carp and haarder (*Mugil soiuy*) were introduced and successfully acclimatized especially in the estuarine waters of the Azov and Black seas basin. Haarder, recommended for the Southern seas by professor B.N. Kazansky, was successfully acclimatized in the Azov-Black seas basin. The result was a new selfreproducting stock (**Fig.** 43). Haarder produced several generations and now is included into the list of marketable fishes (Volovik et al. 1997). At the moment, the haarder stock is estimated as 40,000–50,000 t. Catches of this mullet recently reached 1,600–3,500 t (Pryakhin 1998). Fisheries experts put the maximum sustainable yield at 10,000–15,000 t.

Despite high abundance of the haarder in the Azov-Black seas basin some biological aspects of its reproduction in the area of introduction remain unrevealed. Fecundity of males and females, duration and parameters of spawning at different sites of the habitat are not yet known. Interrelations of haarder with the aboriginal species of fish and their role in marine ecosystems are still unclear (Gubanov and Serobaba 1997, Pryakhin 1997). Introduction of mullets and haarder into the Azov Sea and introduction of golden mullet into the Caspian Sea caused undesirable competition for food. For example, migrants introduced to the Caspian Sea doubled their growth rate and by 1.5 fold exceed their original size. Some specimens of golden mullet are 70 cm in length.

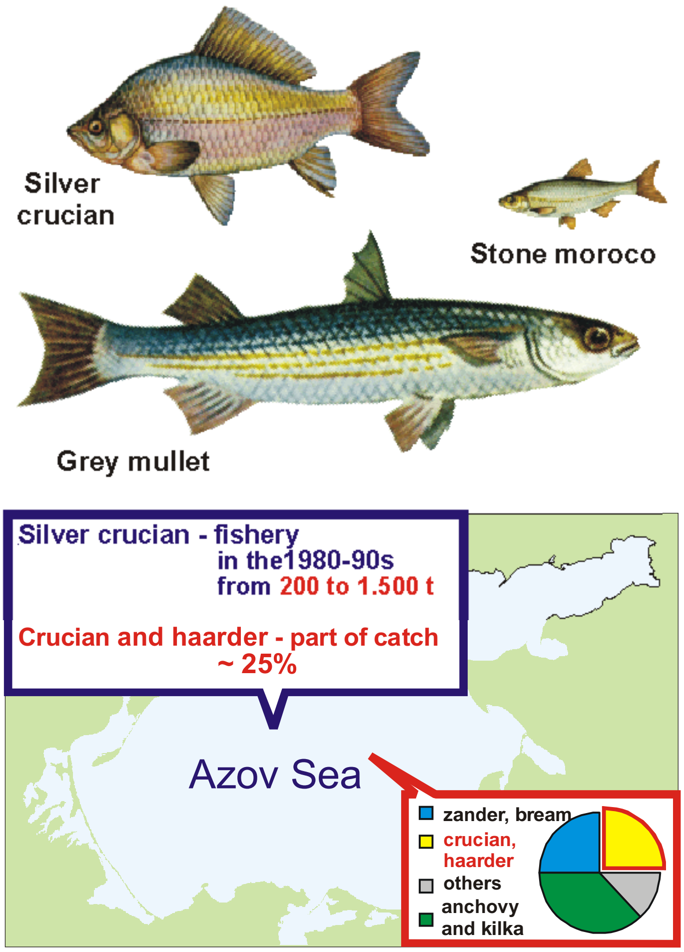


Fig. 43. Expansion of fishes-introducers in the Azov Sea basin (by the data of Volovik 1998, Abramenko et al.1998)

Other cases of introduction are of a more disputable nature. Humpback salmon and greenling did not acclimatize quite well to the conditions of the Barents and the White seas. Transferring of humpback salmon larvae started 40 years ago, but it was only in 1987, after adult fish matured in the sea, when adult fish were detected returning to the spawning areas in the rivers of the White Sea basin. Humpback returning was registered in 1989, 1991, 1993, 1995. These were generations of fish that had spawned in the rivers of the Barents Sea Basin. Yet catches did not exceed 100–200 t per year. The question naturally arises whether there was any biological or commercial reason for introducing humpback salmon. It is so far unclear what ecological niche this fish may occupy and whether it will be competing with salmon for convenient spawning areas (Zhuravleva and Zenzerov 1998).

All above mentioned examples prove fundamental postulates of modern hydrobiology and ecology: ecosystem resources are nearly always being used completely even when the number of species decreases. Also even if biodiversity in most communities is poor, they are saturated by individuals. (Alimov 1998). That is why the thesis that remaining species expand their area using all vacant resources may be said to be true for marine reservoirs. The only question is how useful such changes are from the viewpoint of bioresources.

MAIN CAUSES OF MARINE ECOSYSTEMS TRANSFORMATION

Population and ecosystem evolution of marine biota is determined by natural environmental development. Climatic changes are without any doubt the crucial factor. Still, the human activities in the 20th century were not the least cause of undesirable changes in marine ecosystems of commercial importance. Seismic surveys, pilot shelf boring, exploitation of many thousands of vessels, growing discharge of sewage and industrial wastes, radioactive background and many other are to be added to the list (G.G. Matishov et al. 1997, *Chemical processes in the ecosystems of the northern seas*).

RUN-OFF REGULATION AND LOSS OF SPAWNING AREAS

Large scale construction of dykes on the Volga, Don, Dnieper rivers caused dramatic changes in bioproductivity of the seas in the southern part of Russia (**Fig.** 44). Run-off regulation led to loss of spawning areas of sturgeon family and other valuable marketable species and to drastic decrease of river outflow to the Azov, Caspian and Black seas. Biochemical and hydrochemical balance of the reservoirs was upset, too. It turned out a catastrophe for reservoirs with low salinity. River outflow to the Azov Sea decreased by over 30 % (24 m^3 per year) after building of only one dyke in Tsymlansk. The dam cut off the sea all spawning areas of white sturgeon and up to 50 % spawning areas of sturgeon, sevryga and herring. Long term shortage of fresh water was compensated by salt water of the Black Sea. Observations carried out for decades show, that the Azov Sea receives 30–40 km^3 of waters of the Black Sea. Total outflow deficiency was compensated by increase in salinity of the Azov Sea by average 3‰ (Bronfman et al. 1979).

Spring freshet reduction to 35% of annual mass flow brought about a general decrease in abundance, supply and redistribution of biogenes which were captured between the dam. The Azov Sea is going through the predicted period of salinization. Abnormal salinity brought down the freezing point of sea water and formation of ice here is now delayed. As the result, shallow waters cool down right to the bottom to such extent, that fish body fluids freeze and blood curdles. High winter water level in reservoirs with regulated run-off causes intensive «blooming» of phytoplankton in February-March (Sapoznikov 1995, Kovaleva, 1998). This brought about considerable redistribution of positions of certain groups of phyto- and zooplankton and benthos. E.g. Blue-green microalgae nearly lost their position altogether in marine ecosystem in the 1970s. Pyrophyte algae abundance dropped dramatically and influence of diatomaceous algae grew stronger. Such undesirable aliens as *Ctenophora* moved in.

Phytoplankton biomass grew up by dozens of times during the past 20 years in the North–West of the Black Sea (Zaitsev 1992, Fashchuk 1998). «Red tide» is consequence of excessive accumulation in the bottom layer of organic matter formed after «blooming» algae die off. At the present time its quantity increased by four times and may vary during summer time from 15 to 50 mg/l (Torgunova 1994). This index for the Black Sea waters in general has grown over last 30 years by 6–8 kg/m^2 (Torgunova 1994). Consequently it increased oxidation rate of excessive organic matter in bottom layer by 3–4 times as compared to natural oxidation rate (Faschuk and Sapozhnikov 1999).

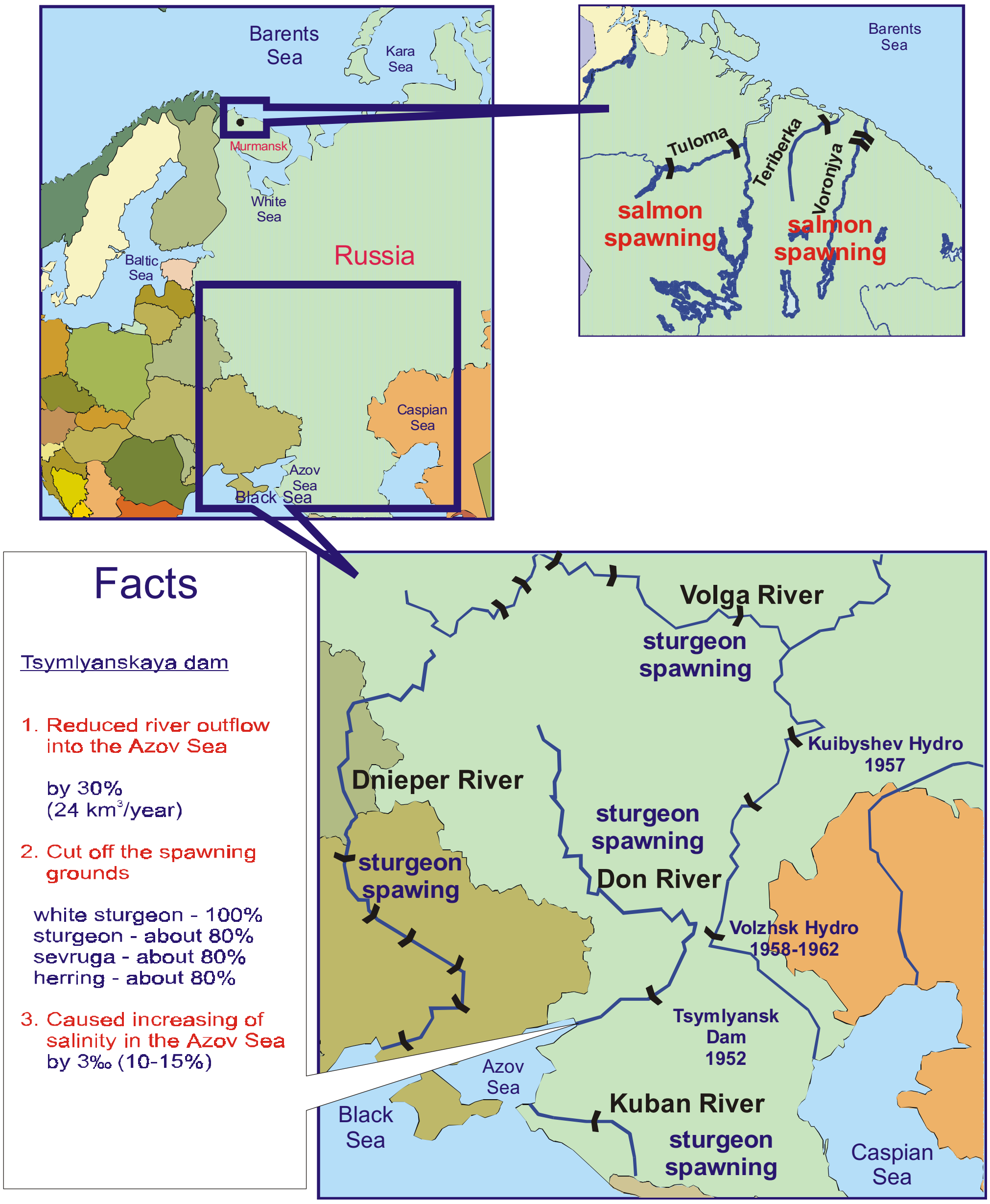


Fig. 44. Run-off regulation and loss of spawning grounds (rivers with cascades of dams)

The presence of medusa in the Azov Sea implies that water salinity is high. Every time its concentration reaches maximum admissible threshold, danger of mass death through low water oxygen in winter appears. In 1974, the total weight of medusa migrated from the Black Sea comprised 2 mln t, in 1976 its biomass was over 16 mln t.

Thus run-off regulation, discharge of sewage and industrial wastes and fertilizers cause increase of microalgae biomass by dozens of times, «blooming» and phenomenon of mass death. Hydrogen sulfide contamination of benthic waters expanded over vast areas in the North-West of the Azov and the Black seas (**Fig.** 45).Oxygen deficiency annually causes death in bottom communities and fish, its total biomass amounts up to several millions tons.

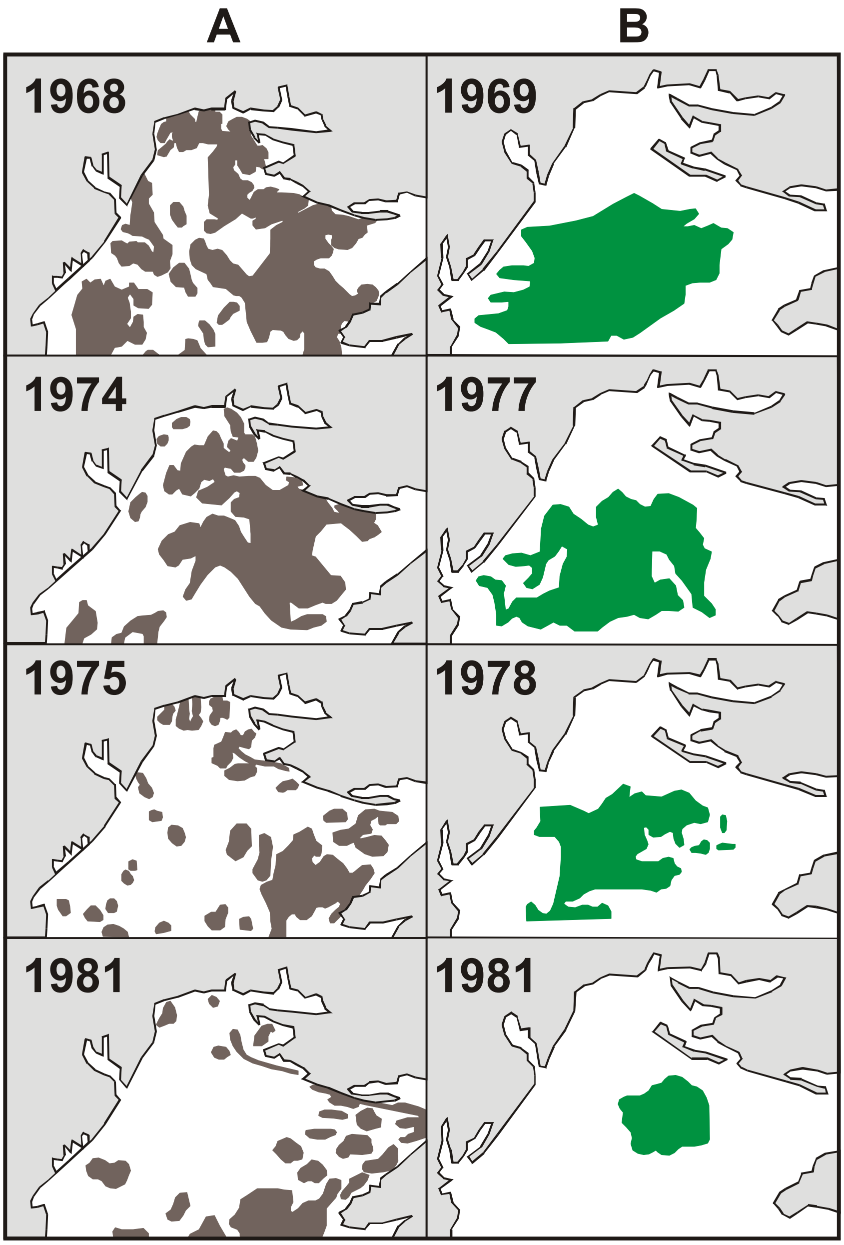


Fig. 45. Shrinking of the phyllophora (B) and blue mussels (A) areas in connection with the hydrogen sulphide contamination on the north-west part of the Black Sea shelf (the 1960-80s) (by Faschuk, 1995)

In the Barents and White seas basins the same situation can be found at major rivers (Teriberka, Tuloma, Voronja) of Kola peninsula where 17 dams prevent salmon from passing natural spawning grounds.

Water intake equipment of all kinds contributes to destruction of sea reservoirs bioproductivity. E.g. There are approximately 1100 water intakes only in the Azov-Don basin extracting annually 7 km^3 of river outflow, 4 km^3 of them are not returned (Kovtun and Syrovatka 1997). Despite introduction of fish protecting devices to 80% of water intakes their efficiency is still low and therefore annual fish death rate still amounts to thousands of tons.

MARINE NAVIGATION AND RIVER-SEA TRANSPORTATION

As has been stated before, thousands of vessels traveling from continent to continent bring with them exotic fauna. Sea organisms are occasionally brought in attached to the bottoms of vessels or with ballast waters. Many aliens are characterized by high ecological flexibility and high rate of natural reproduction, and they develop abundant communities and consequently change species structure and food pattern of ecosystem.

Sea river shipping is one of the most negative factors. Its role radically changed with the collapse of the USSR and the consequent increase in importance of ports in the South of Russia (Astrakhan, Azov, Taganrog, etc.). Vessels with 3–5m draught disturb environmental balance of organisms inhabiting shallow waters (5–10 m). Other shipping related phenomena are dredging, acoustic pollution, cavitation, stirring up of silt bottom, deforestation of coastline and oil spillage. Through the canals dug in shallow water of the Azov Sea alone 7,000 vessels pass annually and this number is still growing.

CHEMICAL CONTAMINATION OF MARINE ENVIRONMENT

Influence of chemical contamination on marine biota life cycle is well known (**Fig.** 46). Contemporary totality of data provides us with firm grounds to postulate, that offshore ecosystems of the Barents and the White seas are characterized by a very low degree of chemical contaminants accumulation in biota (Matishov 1992, Matishov et al. 1994; G.G. Matishov et al. 1997, *Chemical processes in the ecosystems of the northern seas*). E.g. Concentration of artificial radionuclides in marine organisms is lower than natural background (**Fig.** 47). Semi-isolated contained sea basins situated in the areas with high levels of industrial development are most contaminated. These are the Azov, the Baltic sea, the north-west of the Black Sea, and the northern part of the Caspian Sea. Contaminants concentration in environment and biota on many of these shelves exceeds maximum allowable concentration (MAC). E. g. The most dangerous for the Black and Azov seas industries processing oil hydrocarbons are situated in Sevastopol, Novorossiysk, Batumi (**Fig.** 48). The Dnieper, Dniester and Danube rivers bring 60% of the total industrial and domestic sewage annually (about 1 km^3). Anomalous concentrations of phenol in water (maximum allowable concentration exceeded by 52 times) led to closing down of beaches in 1987 in Odessa (Fashchuk 1998). The Black Sea received several tons of pesticides annually which arrived through the Straight of Kerch as their concentration in the Azov Sea exceeded that in the Black Sea by the order of magnitude (434 nanograms/ liter).

Heavy metals represent the dangerous toxicants most often registered in sea water. Concentration of iron in sea water in the Caspian Sea increased considerably over last 15 years: c.f. concentration of iron in the 1980s was 50 mcg/l, concentration of 200 mcg/l was registered at the western coast recently which is 4–5 MACs (Kostrov and Panarin 1997). Concentration of metals in fish organisms (average) ranges from 0.2 to 200 mg/kg: concentration of iron ranges from 24.7 (goby) to 126 (Caspian roach, goby); zinc – from 11.8 (goby) to 53.0 (Caspian roach, zarthe). Concentration of pollutants including heavy metals in bottom sediments of sea reservoirs is an extra danger. Most of the valuable marketable fishes, crustaceans and mollusks live at bottom or close to bottom.

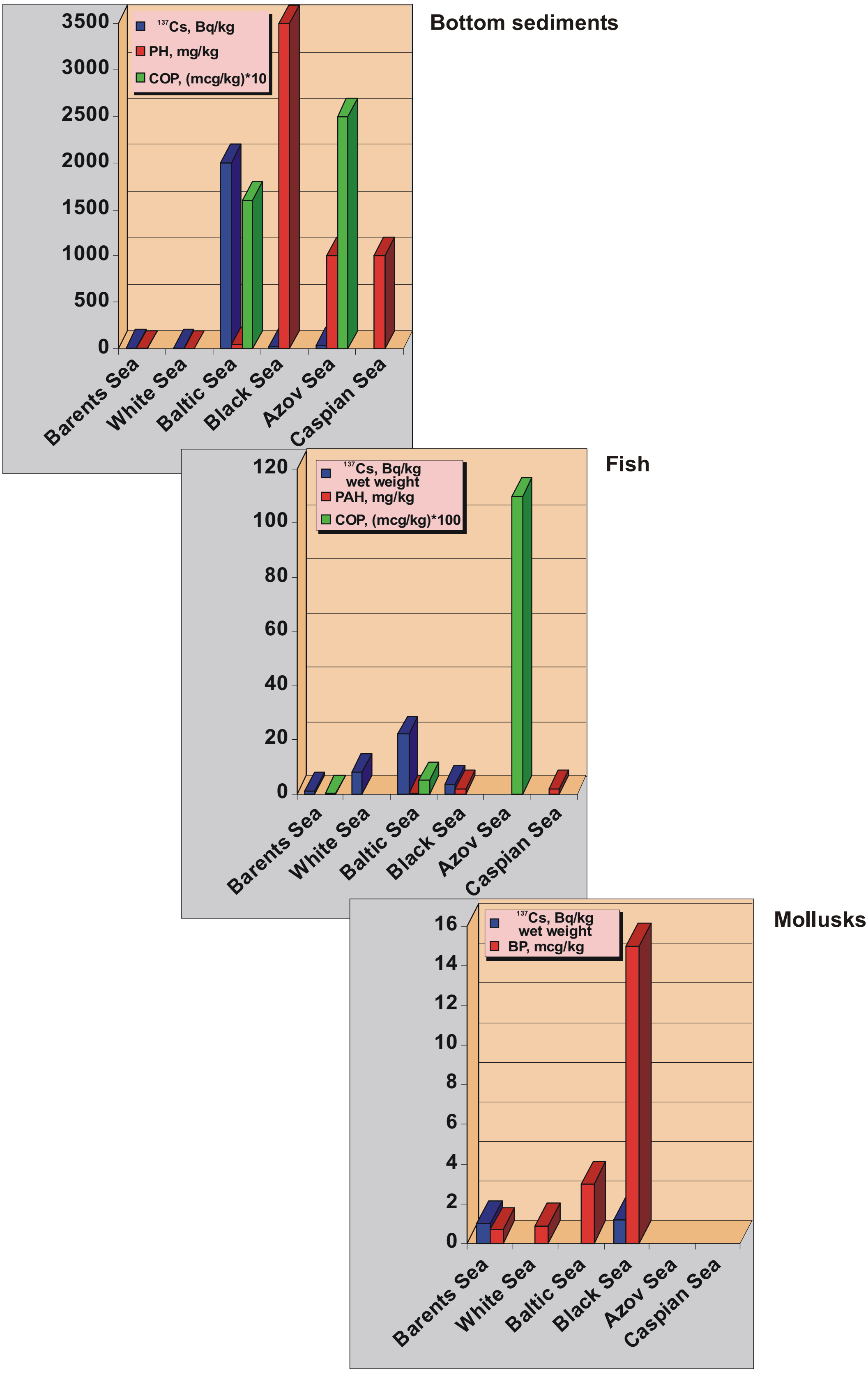


Fig. 46. Artificial radio-nuclides (^{137}Cs), oil hydrocarbons and chlororganic pesticides in bottom sediments, commercial fishes, and mollusks in the seas of Russia (comparative analysis)

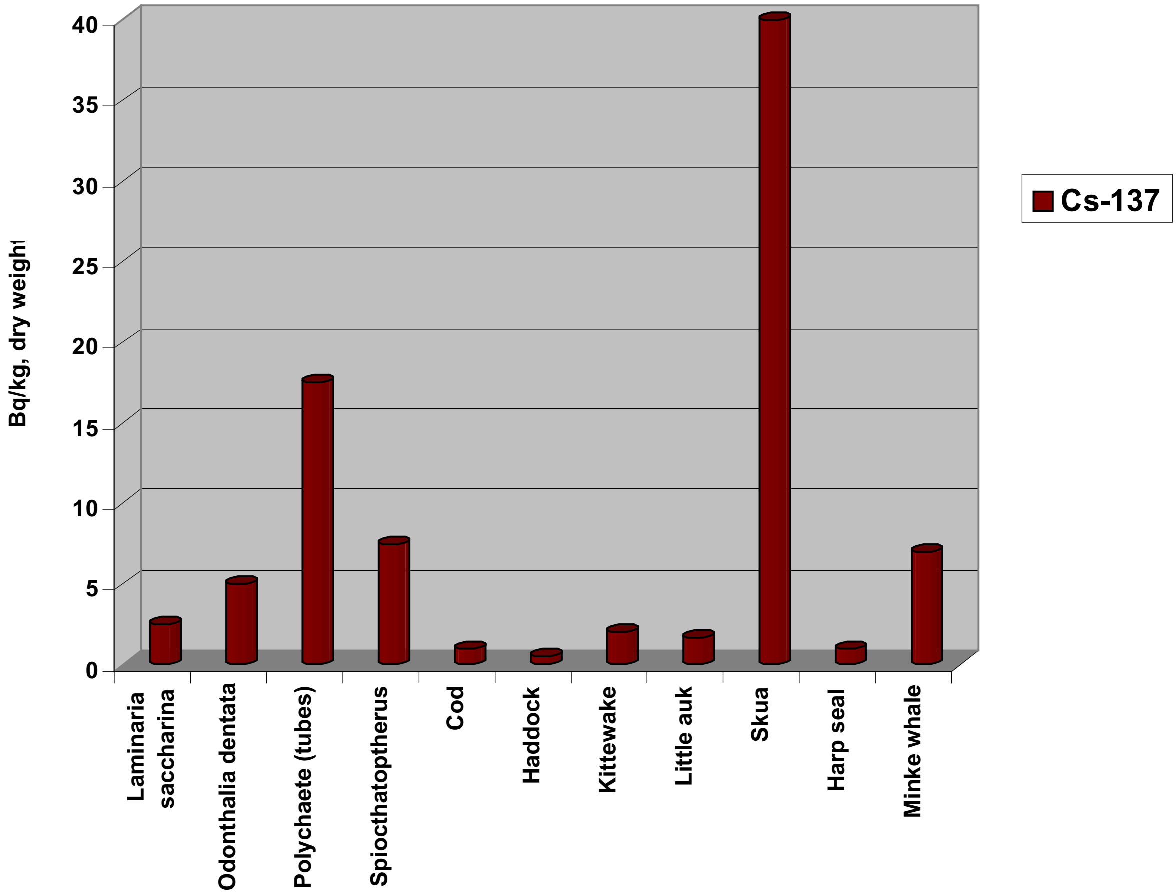


Fig. 47. Concentration of ^{137}Cs in different organisms inhabiting the Barents Sea (Matishov G. G. and Marishov D .G. et al. 1997)

Consequently contamination is transferred through food chain to birds, seals (that is to the top of the ecological pyramid) and to humans. E.g. Concentration of ^{137}Cs in the bottom sediments of Bay of Taganrog is 100 Bq/kg and in the Barents Sea shelf only 1 to 20 Bq/kg (**Fig.** 49, 50) (Matishov et al. 1998).

Long term contamination of the Black and Azov seas basins is one of the reason for changes in spawning behavior, density and schedule of adult fish migration towards coastline, year-classes characteristics and quality of gonad products. The leading role in development of these negative factors belongs to such accumulating toxicants as lead (in liver), and mercury and some DDT metabolites (in gonads) (Dudkin et al. 1997). General disorders of reproductive function detected in many fishes, including sturgeon family, are hermaphroditism, disintegration and resorbtion of gametes, oocyte amitosis at the stage of cytoplasm growth. All these in the course of time will result in degradation of genetic resources of populations.

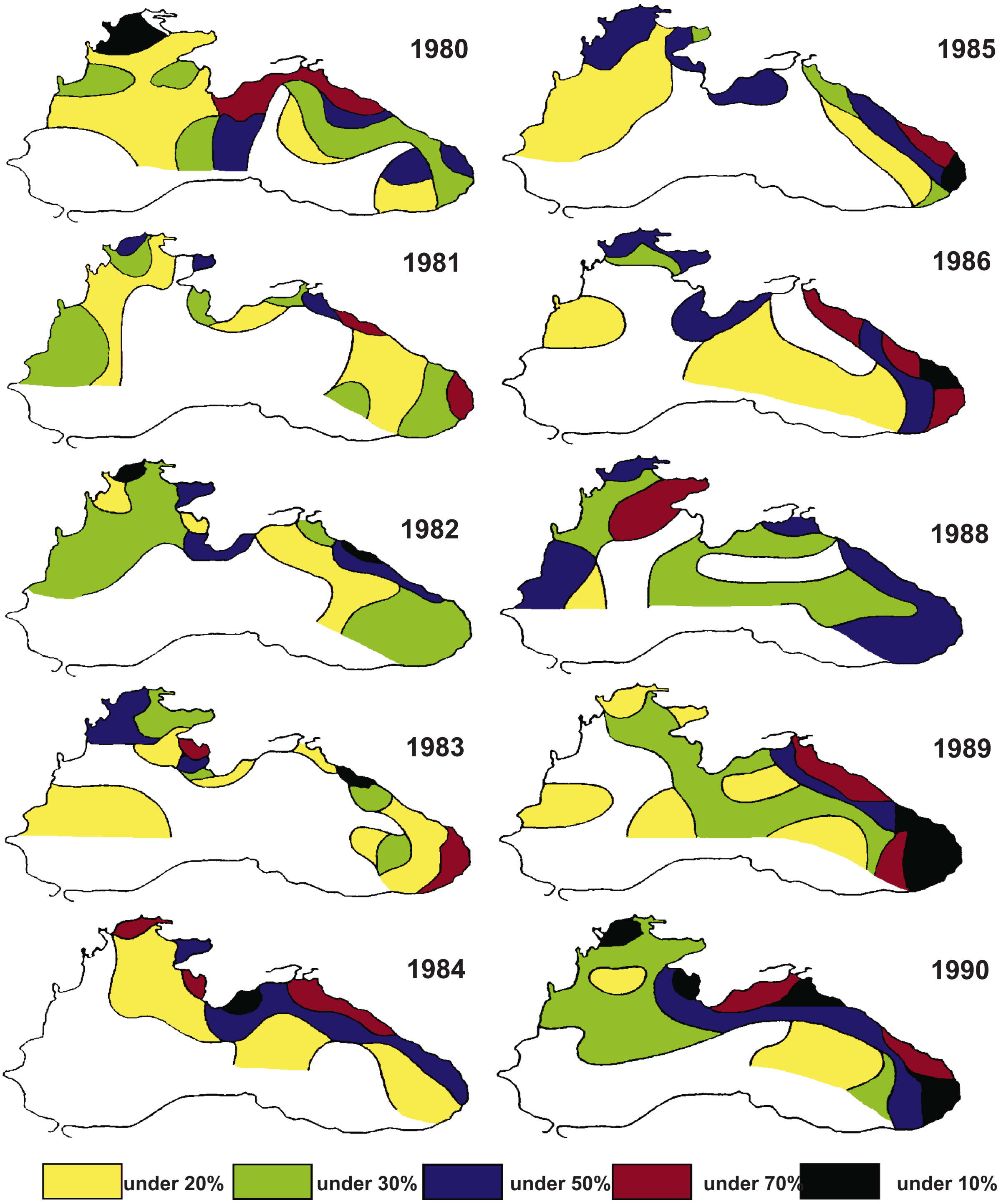


Fig. 48. Frequency of oil products films (%) on the Black Sea surface by the aerial observations data (Fashchuk 1998)

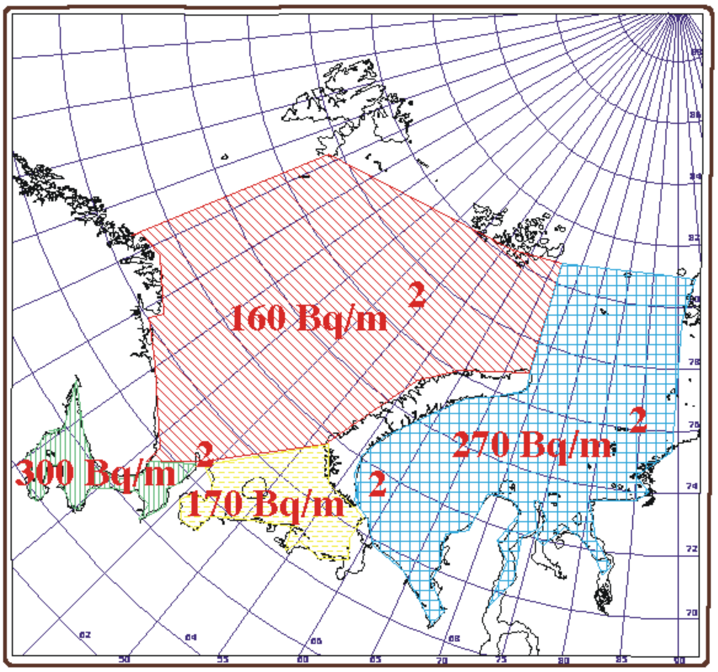


Fig. 49. Maximum concentrations of ^{137}Cs (Bq/m^2) in the bottom sediments of the Barents, the Kara and the White seas

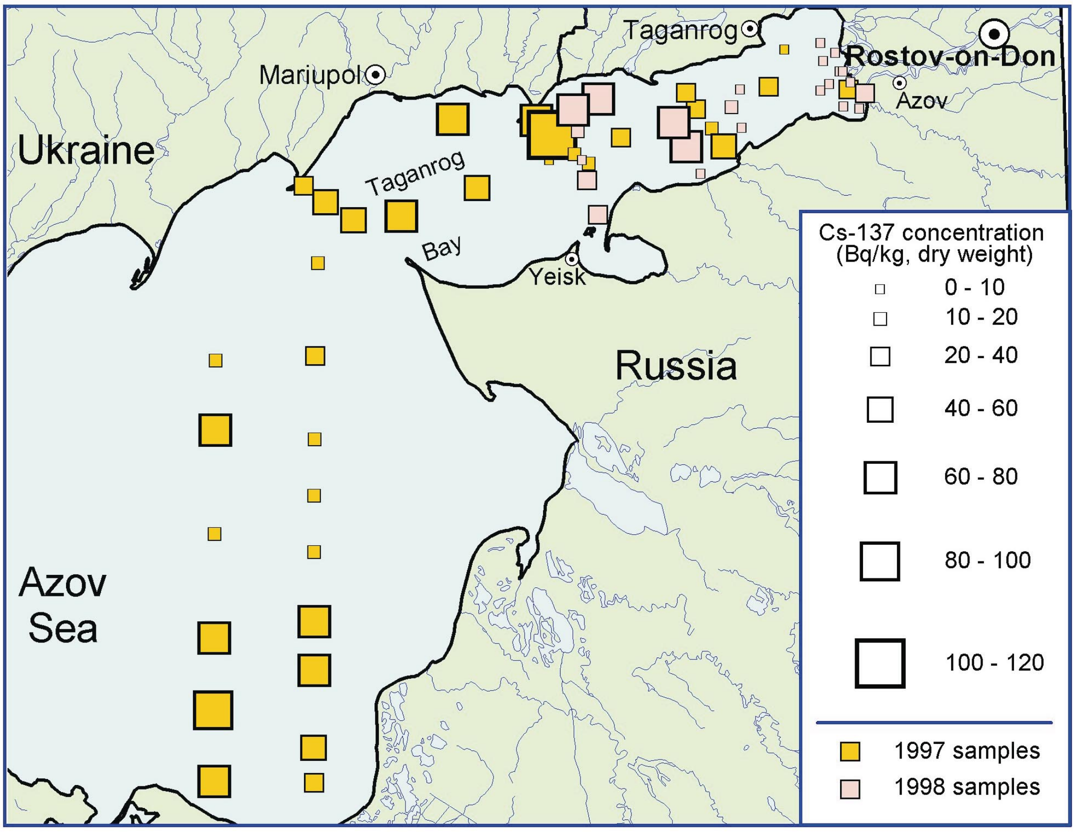


Fig. 50. Contents of ^{137}Cs in the surface layer of bottom sediments in the Azov Sea (based on MMBI investigations in 1997-98)

FISHERY MORTALITY IS THE MAJOR THREAT

Excessive stress of whale hunting and fisheries of countries that exercise whaling, sealing, fishing and exploitation of other bioresources (mollusks, algae, etc.) is to be regarded as the major source of stress among other anthropogenic factors affecting ecosystems in the 20th century. The over exploitation by fisheries and hunters is internationally recognized by scientists and practical workers (**Fig.** 51). Obviously death by fishery triggered irreversible disruption of inter-relations within marine ecosystems and particularly in the marketable stock structure.

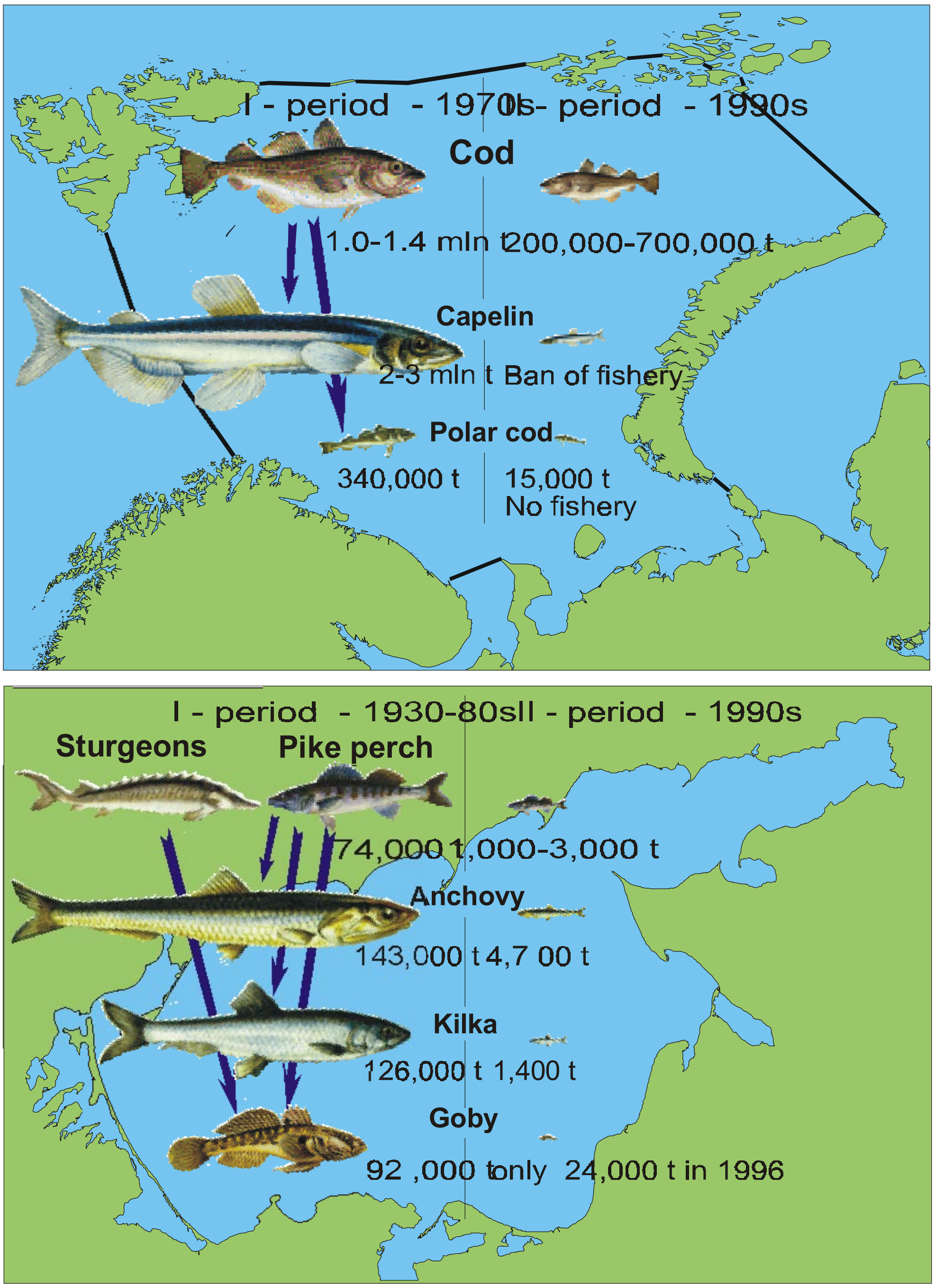


Fig. 51. Ratio of the main fish species catch and their forage objects in the Barents and Azov Sea

Fish is the key element of ecosystems and a bioresource of primary importance. Natural stock number fluctuations are characteristic of all fish species. Marketable fishes serve as an indicator of marine ecosystem dynamics and death by fishing analysis clearly shows it. Yields of fisheries back in the past in the Barents Sea could comprise up to 4 mln t and in each of the Southern seas yields were 400,000–600,000 t. It is but natural that yield of such traditional marketable species as salmon, sturgeon, cod, zander and others decreased 10 fold and more (**Fig.** 52).

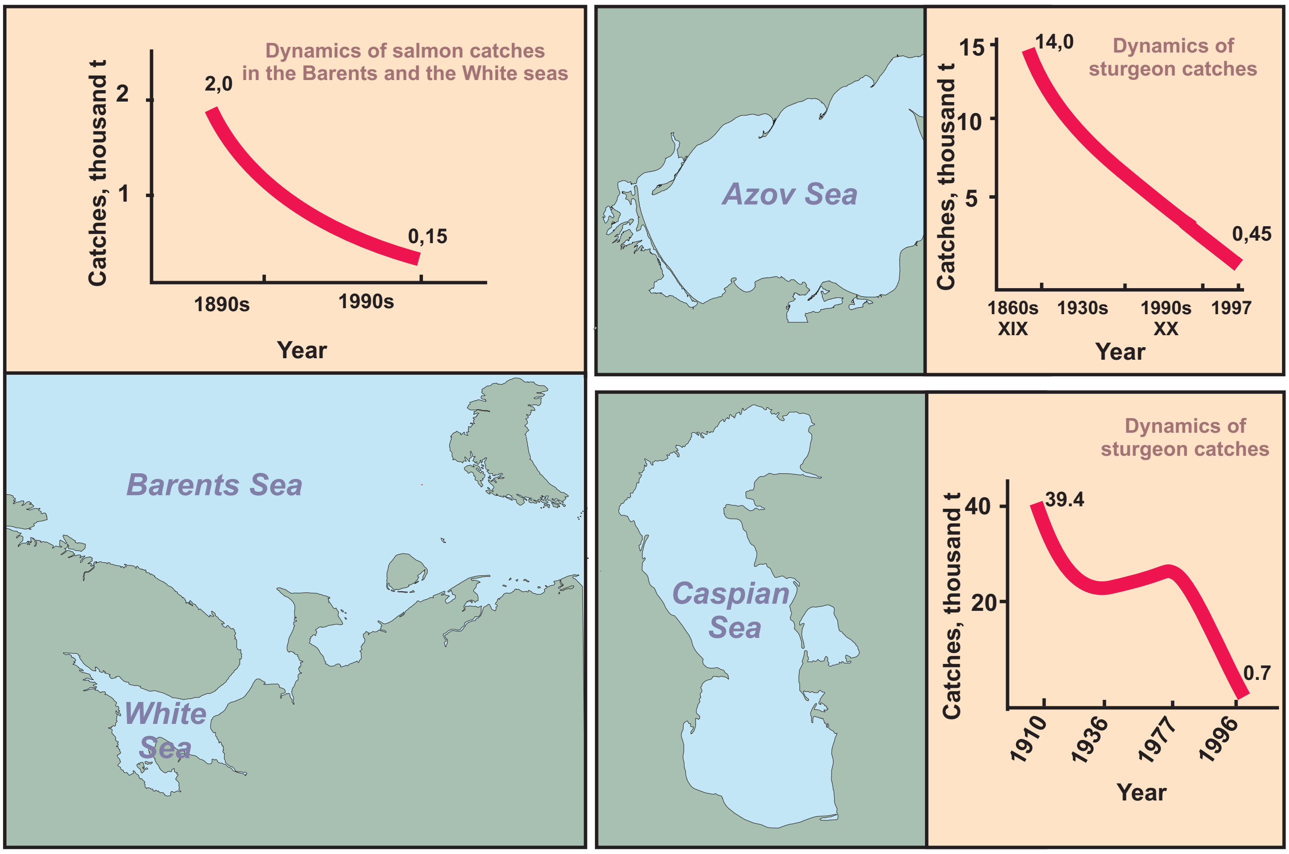


Fig. 52. Dynamics of valuable fish species catches in the seas of the European part of Russia

Reduction of yields and alteration of valuable and not valuable species ratio can be observed in all European seas (**Fig.** 53, 54, 25, 27, 31). Catch structure modification is the general trend. Alongside decrease in yields smaller fishes earlier regarded as not valuable have come to form their core.

The Barents Sea fisheries dynamics (**Fig.** 53, 31) show that large scale fishery in this basin started only in the 1950s that is very much later than in the Southern seas. Average catch was very high reaching 3 mln tons and it mainly consisted of valuable fishes and herring is one of them. By the early 1970s, as herring stock was exhausted, new species (capelin, Arctic cod) were introduced into mass extraction comprising more than half of total catch. In several years Arctic cod suffered the fate of herring. At the same time there were registered peak catches of halibut, perch, wolf fish (200,000 t).Traditional fish deficiency was helped by extensive extraction of capelin. Capelin vanished in 1986, yet herring stock had not recovered. That period is characterized by the lowest yields (**Fig.** 55).

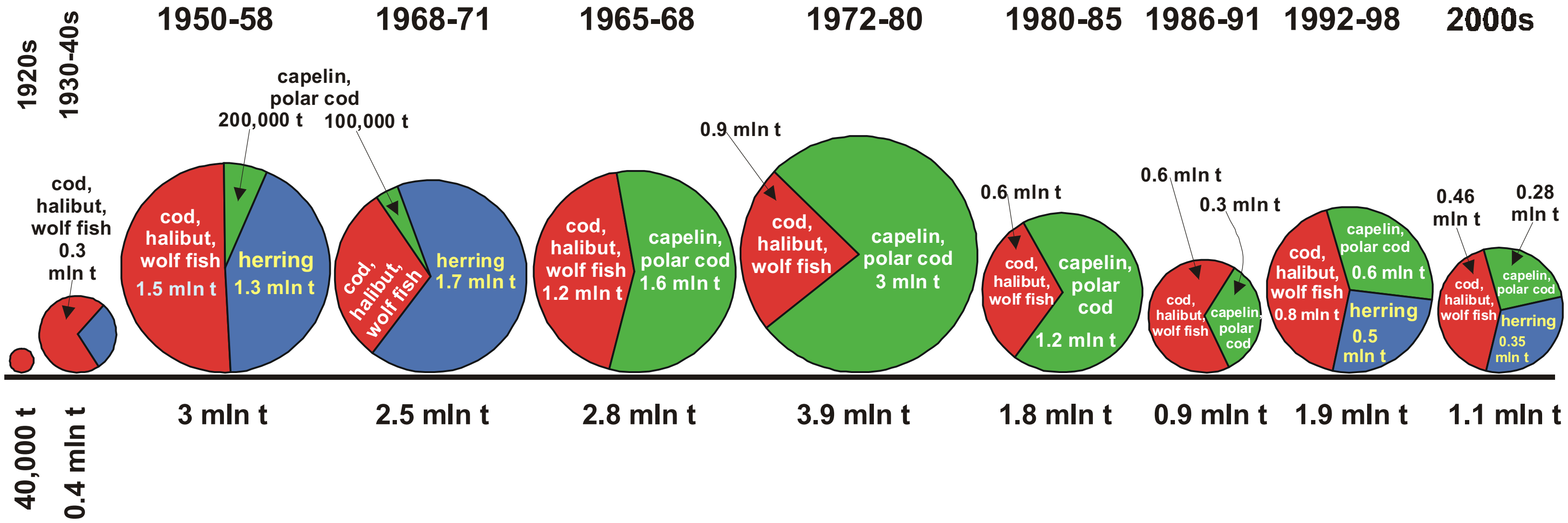


Fig. 53. Generalized scheme of dynamics of catch of both valuable and low-value fish species in the Barents Sea

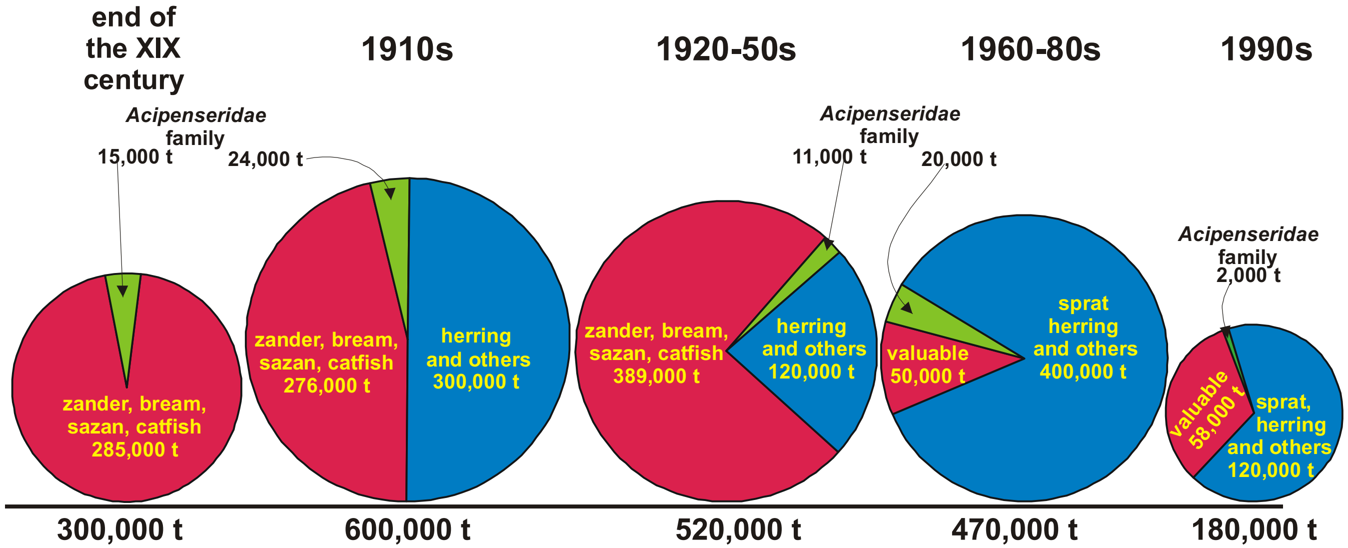


Fig. 54. Generalized scheme of dynamics of catch of both valuable and low-value fish species in the Caspian Sea (by the materials of Ivanov V. P. 1999)

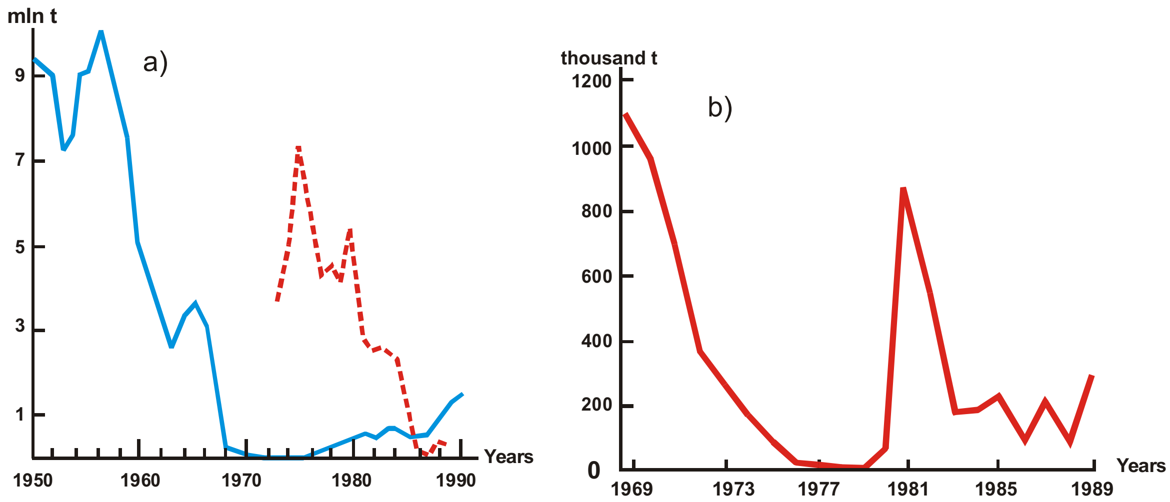


Fig. 55. Dynamics of abundance of capelin and the spawning Atlantic- Scandinavian herring (a) and polar cod (b) due to over-exploitation (Vader et al. 1989, I. Borkin's personal message)

That was the fish resources exploitation trend in the richest of the seas studied in this book. Barents Sea cod deserves separate analysis as key element of the ecosystem (**Fig.** 56). It has been heavily exploited on account of its high commercial value despite shortage of food, regardless of biological consequences. Nearly half of its stock is extracted annually instead of admissible quantity equal to one fifth which is a sure way to degradation of Barents sea cod (**Fig.** 53, 54).

Cod stock depletion is accounted for not only by overexploitation of cod itself but also by extraction of its food objects, capelin and shrimp. Overcatch of the latter reduces food resources, leads to grazing upon juveniles of its own kind (cannibalism), growth rate decrease and population reproductive capacity reduction which hinder recovery of the stock despite occurrence of rich year-classes. Overcatch of Arctic cod and capelin caused decrease not only in stock of cod but also in number of seals that had to alter their habitual routes of migration because lack of food and perished near Norwegian coast. In the bird colonies population of birds feeding on fish decreased sharply (**Fig.** 64). Cod subsistence on other food objects brought misbalance into the Barents Sea ecosystem (Orlova and Matishov 1993).

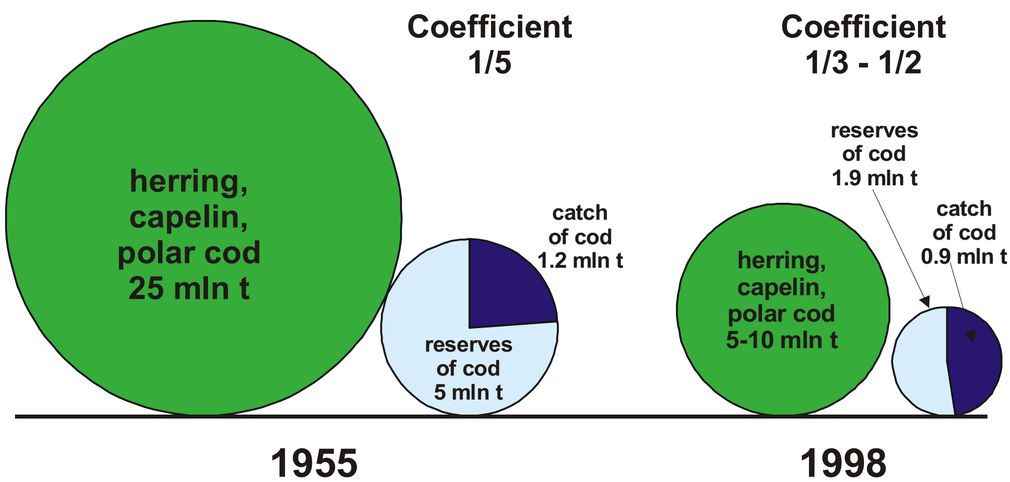


Fig. 56. The Barents Sea cod catch compared to its own stock and to stocks of other pelagic fishes

The detected trends manifest themselves much more distinctly in the Southern seas. Sturgeon stock exploitation in the Caspian Sea started as early as the 16th century. By the end of the 19th century, the catch of valuable species amounted to 300,000 t including 40,000 t of sturgeon. Ultimate overcatch took place by the mid of the 19th century. It is noteworthy, that it had happened before the dams were erected and agriculture was flooded with chemicals. Over last 40 years sprat is predominant in catch pattern and negligible catch of sturgeon is maintained by rearing (**Fig.** 54).

The Azov Sea represents accelerated modification of the Caspian model of bioresources exploitation. In the course of 150 years one of the world's richest reservoir has completely lost its commercial importance. Only valuable fishes were captured until the middle of the 20th century despite continuous decline in yields. Quantitative breakthrough happened in the 1950–60s when mass fishing of white sturgeon and Caspian sturgeon food object (Azov goby) added to other negative factors which will be discussed later. Fate of the Azov Sea is as tragic as that of the Aral (**Fig.** 25). The role of seabirds in the ecosystems should not be underestimated. Multimillion bird colonies graze upon small fish, crustaceans and supply coastal waters with biogens. Exhaustion of not valuable fish caused food deficiency and dramatic decrease in populations of bird colonies. Coincidence in time of heavy fishing and poor reproduction leads to collapse of fish stock itself which is followed by degradation of bird colonies.

Dramatic multifold fall in murre population during one year happened on the Bear Island. Food deficiency resulted in dozens of millions deaths of birds. Migrants from north Atlantic started a gradual occupation of vacant niche.

The situation of bioresources overexploitation is obviously present in all seas. Its consequences affect not only commerce but ecosystem, too. Exhaustion of not valuable mass fishes alone undermined food basis of valuable fish, birds and sea mammals.

Illegal fisheries, small fish discarding, bycatch issue (unused opportunities of multispecies fishery) cause serious concern. All these factors connected with inadequate or non-existent legal regulation, have recently acquired particular importance, as Russian ocean fishery declined.

INTRODUCTION OF NEW SPECIES

Introduction is somehow justified in sea basins with degraded marketable species sector. But proper consideration from the biological point of view has not always been given to it.

Thus food basis of king crab turned out to be more scarce than in the Far East, though feeding rate remained at the same level (**Fig.** 57). King crab diet in the Far East seas primarily consisted of mollusks, but in the Barents sea they mostly graze upon Echinodermata (40% of weight), Polychaeta, fish (Gerasimov and Kotchanov 1997). On account of ample fish and larvae consumption by king crab they are supposed to be responsible for elimination of henfish stock which is a valuable marketable species of the Barents Sea coastal area (Personal message of Karamushko). Annual catch of henfish only by Russian trawlers amounts to 1,500–2,000 t.

A series of studies on Southern seas is devoted to analysis of the consequences of planned introduction of ichthyofauna representatives. For example, studies on fishes occupying differ-

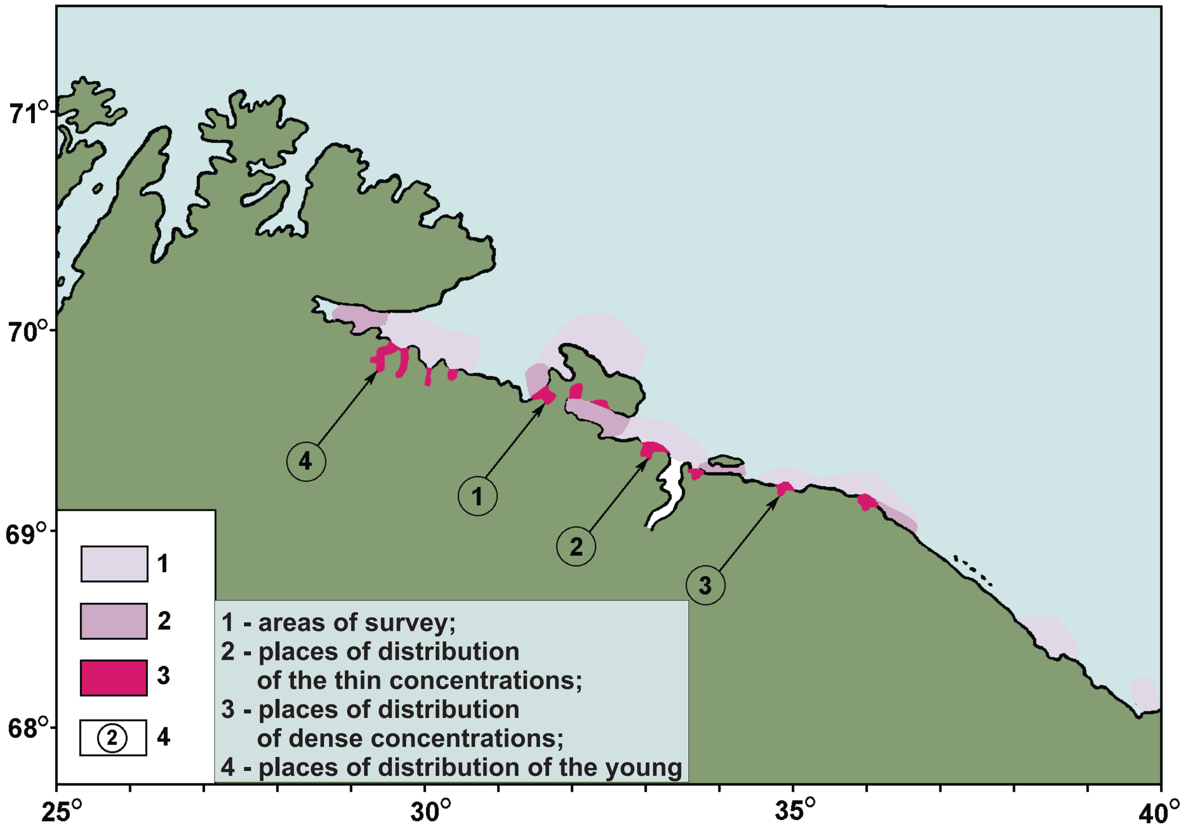


Fig. 57. Distribution of the Kamchatka crab concentrations in the Barents Sea in July-August 1993

ent levels in the food web: white and black amur (plant feeders), pelyad (zooplankton feeder), ship (benthos feeder), zander (predator), leaping grey mullet and golden mullet (detritus feeder) (Rykova 1997). Silver carp was introduced to Tsymlyansk reservoir with respect of phytoplankton primary production like white amur was introduced to deltas of the Don and Volga rivers on the assumption that it would graze upon water surface plants. However, expected ameliorating and commercial results were not achieved, at least «blooming» and eutrophication of delta never stopped. In all cases attempts to produce marketable stocks of above mentioned fish failed.

Leaping grey mullet and golden mullet (detritus feeders) were trying to fit into free food web niche in the Caspian Sea. Abundance of these species obviously matches food basis. Commercial effect is clear, because they grew into commercial stock without interfering with the other species. Introduction of species into reservoirs regardless of their trophic level leads to serious changes in the original ecosystem.

Trophic interrelations that entered the scene after introduction of haarder into the Azov Sea remain unrevealed, too. In new environment haarder size-weight growth, maturation rate growth and broadening of its food preferences have been registered (it started feeding on some kinds of benthos besides detritus) (Gubanov and Serobaba 1997, Pryakhin 1998).

This is a case of undesirable competition of haarder with aboriginal species, especially with unique sturgeon family which are known to be benthophages and predators.

UNBALANCE IN THE BIOLOGICAL PROCESSES OF THE ECOSYSTEM OF THE SEA

A noticeable and in some cases even a significant modification of the species composition took place during the last decade due to the invasion of the introducers and other anthropogenic reasons caused the destruction in the functioning of the marine ecosystems. The destruction manifested itself in the

- impoverishment of the species diversity of the sea fauna;
- changes of the size-age structure of the population;
- destruction of the food connections and increase of natural mortality;
- bioenergetics unbalance;
- destruction of the interconnection host-parasite;
- eutrophication of the estuaries and the shelves shallow-water areas;
- increase of the abundance of the pelagic crawfishes;
- decrease of natural reproduction of the aboriginal biota

All these ecological transformations and deformations separately came to get noticed as early as the 1950–70s and were analyzed more systematically in the 1980s in the papers of MMBI (Matishov et al. 1986; Matishov and Pavlova 1990). Thus, for instance, in all the investigated seas as the result of the degradation of the populations and the habitats of fishes, birds, seals, whales the forage productivity of the ecosystems lowered, but this provided the necessary level of the energetic balance of marine and coastal (on the mainland coasts and archipelagos) animals due to the calory content. This way of development predetermined the deficiency of forage for the marine fauna with quite different food preferences (phytophages, fish grazers, birds grazers etc.).

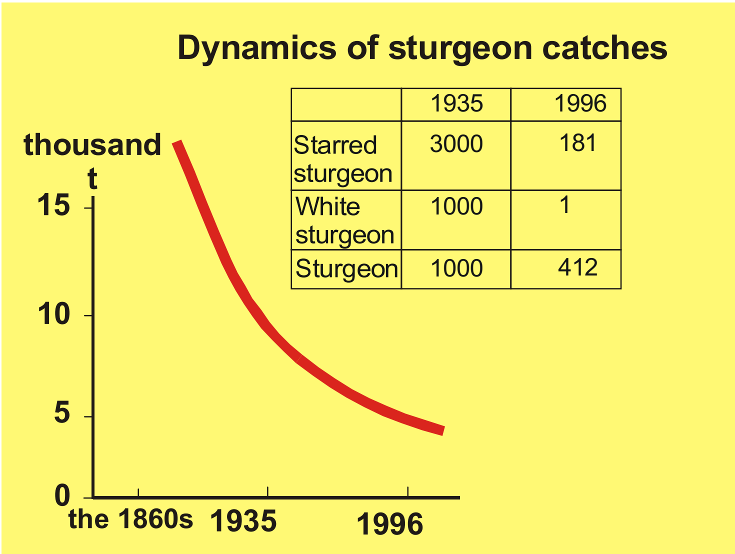
IMPOVERISHMENT OF THE SPECIES DIVERSITY OF THE SEA FAUNA

The dynamics common to all marine ecosystems leads to the situation that alongside the whales, seals, birds many valuable fish species happen to be under the threat of extinction. This is especially typical of the Caspian Sea.

During the last decade, the species diversity progressively decreased (**Fig.** 58). In the Azov Sea 23 of 62 fish species which occurred earlier are not detected anymore (Tsunikova 1997). The above mentioned process finds its manifestation in the fact that only the Azov Sea – the Don River zarthe population preserves its commercial importance out of the 3 populations of zarthe inhabiting the Azov-Black seas basin. In the Dnieper River commercial catches of this fish during last 5 years are not observed. The Kuban River population of zarthe is also on the verge of extinction (Belousov 1998).

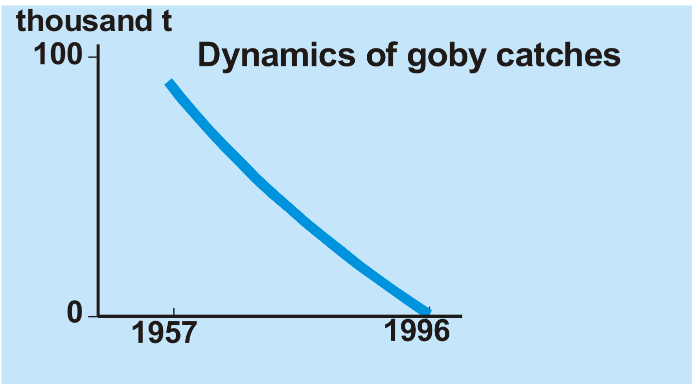
Endangered valuable fish species

The Caspian Sea (Pavlov 1994)
Caspian lamprey *Caspiomyzon wagnery*
Spiny sturgeon *Acipenser nudiventris*
Caspian salmon *Salmo trutta caspius*
Sheefish *Stenodus leucichthys*
Caspian shemaya *Chalcalburnus calcoides calcoides*



	1935	1996
Starred sturgeon	3000	181
White sturgeon	1000	1
Sturgeon	1000	412

Species	State of the populations	
	1860s	1980-90s
Sturgeon	All the species are relatively scarce in catches and their ratio is determined by the abundance of the population	Low abundance (supported only by the artifical restoration)
Starred sturgeon		Low abundance
White sturgeon		Occurs very seldom
Sterlyad		In missing
Ship		In missing
		In the 1980-90s the ban of sturgeon fishery at seas is introduced



Fish species	Food objects
Sturgeon	Molluscs, polychaeta, goby, anchovy
Starred sturgeon	Goby, mollusks, polychaeta
White sturgeon	Goby, mollusks, anchovy, bottom invertebrates
Sterlyad	Larvae, anchovy, sprat, mollusks
Ship	Goby, anchovy, mollusks, sprat

Fig. 58. Decrease in the number of species of the sturgeon in the Azov Sea

Zanthe *Vimba vimba perca*
Caspian barbel *Barbus brachycephalus caspicus*
Tera barbel *B. ciscaucasicus*
Bulat-mai barbel *B. capito*
Sea zander *Stizostedion marina*
The Sea of Azov (Volovik et al. 1996)
Starred sturgeon *Acipenser stellatus*
Great (white) sturgeon *Huso huso*
European carp *Cyprinus carpio*
European eels *Silurus glanis*
Gobies *Neogobis sp*.
Kerch shad *Alosa pontica*
Black Sea shad *Alosa maeotica*
Black Sea turbot *Psetta maeotica*
European (mud) flounder *Platichthys luscus*
Volga shad *Alosa kessleri volgensis*

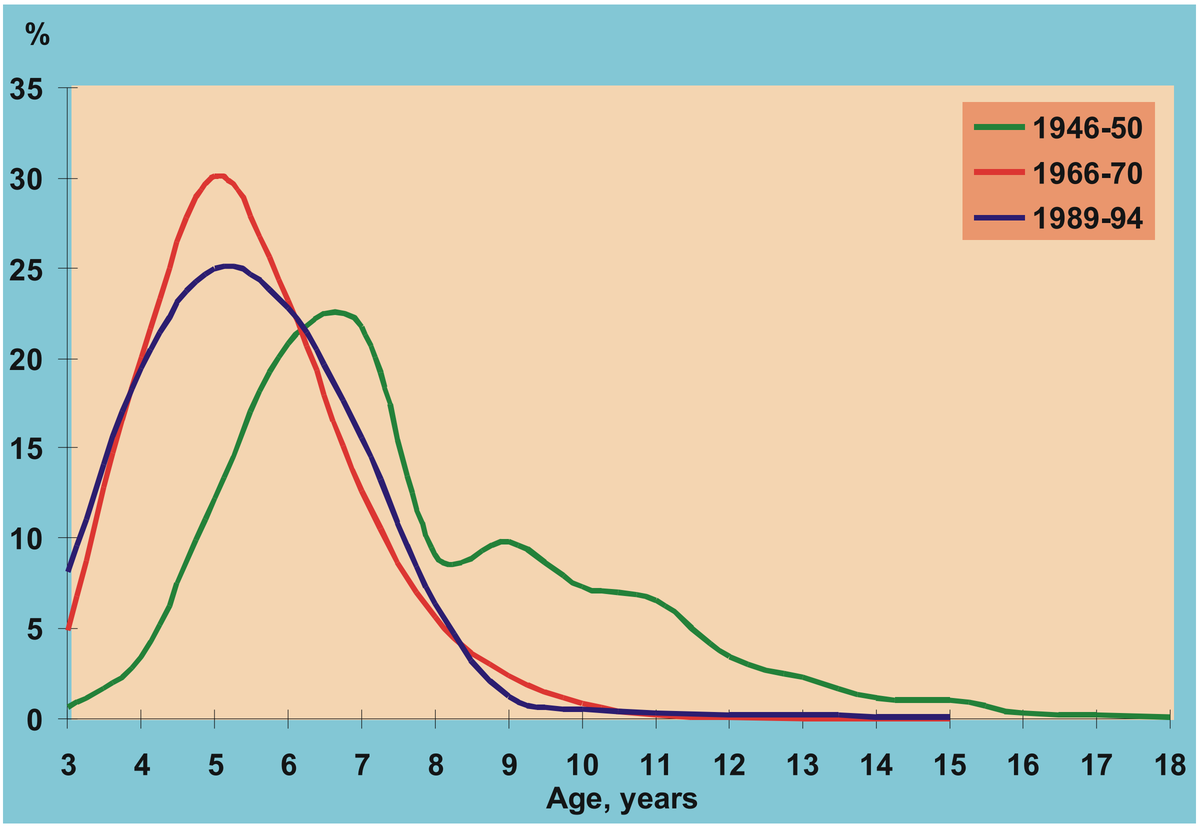
The increase of salinity in the Azov Sea promoted development of high concentrations of the coelenterates: in 1975 the jelly fishes *Aurelia aurita* and *Rhizostoma pulmo* occurred in large amounts, since 1989 expansion of the comb jelly *Mnemiopsis leidyi* began, other jelly fish species were superseded by the comb jelly, which, obviously, was intensely feeding on zooplankton. Zooplankton species composition was reduced (17 species in 1991 out of 41 in 1971), its absolute abundance decreased from 53.9 to 12.3 thousand specimens/m^3, and biomass – from 2.1 to 0.63 g/m^3 (Partaly 1997).

CHANGES OF THE SIZE-AGE STRUCTURE OF POPULATION

Anthropogenic impact on the marine ecosystems caused not only the fall of the total biomass but influences noticeably the sex and the age structure of the populations of the commercial fish species. (**Fig.** 59). Analysis of the age structure of the cod population in the catches made in 1946–1979 shows that with the increase of the intensification of trawl fishery the fishes of the elder age groups (15–20 years old) practically disappeared in the catches by 1970, by 1980 the 10–15 years old cod was practically absent in the catches At the moment the bulk of the catches is composed of 3–6 years old fish (Borisov 1978, Ponomarenko 1996).

The bulk of the Atlantic cod becomes mature (length is about 90 cm) by the age of 8–10 years. Cod spawns every year, sometimes up to 6–7 times during its life. In natural conditions the maturation growth rate of cod fluctuates depending on the climate, productivity and other factors. If in the 1930–50s more than half of the Lofoten-Barents Sea cod became mature at the age of 10–11 year old, in the 1970s it matured at the age of 8–9 year. (Ponomarenko 1996).

In the Azov Sea, as it is noted in the recent papers of *YugNIRO* (Korkosh and Pronenko 1998), long term changes of the salinity regime and the accumulation of the pollutants on the bottom sediments of the shelf «deforofmed» the species composition of the benthos, which is the main food item for the sturgeons. As the result the growth rates lowered and the length-weight indices decreased. This conclusion is made on the basis of the comparative analysis of the marginal rays of pectoral fins saw preparations for the Azov Sea sturgeons for the years 1922–1924 and 1995.



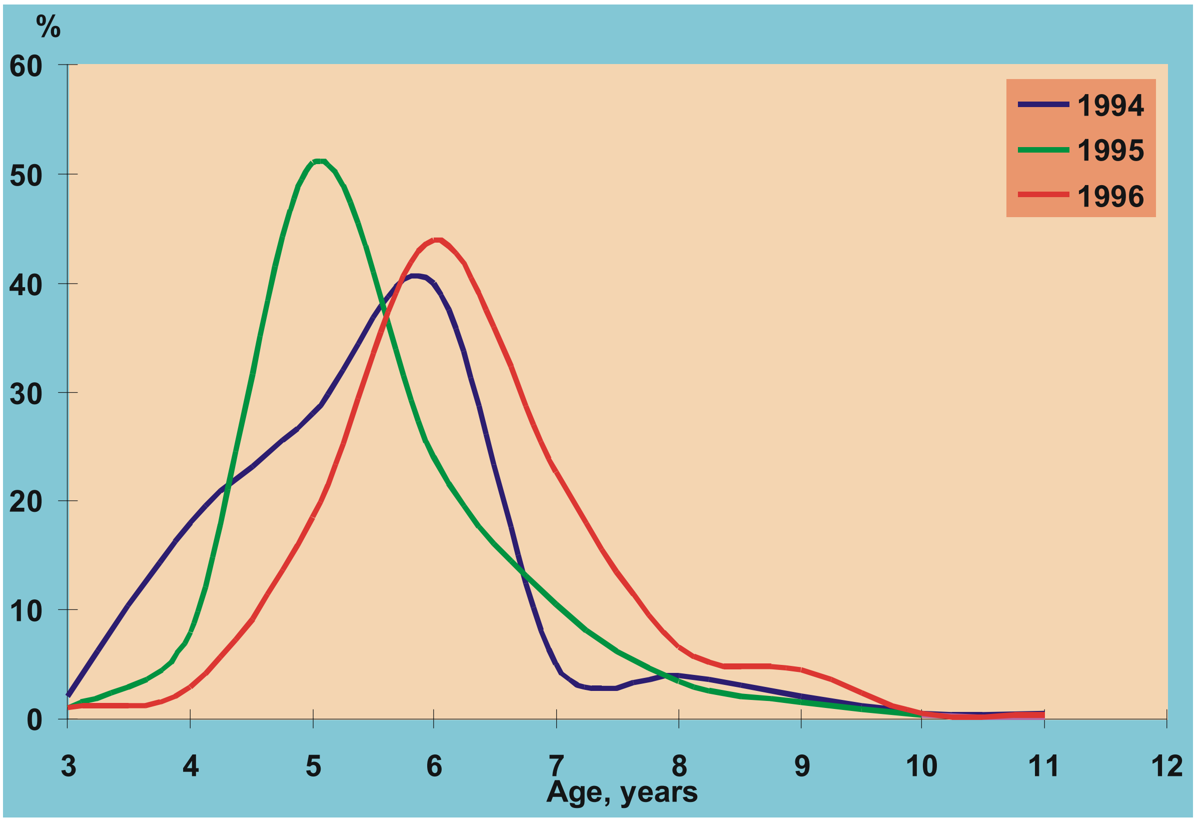


Fig. 59. Age composition of the Arctic-Norwegian cod during different periods and years

BREAKAGE OF THE TROPHIC LINKS AND INCREASE OF NATURAL MORTALITY

Numerous phenomena, for instance, lowering of the predation pressure, mass development of the planktonic crawfishes in the pelagic zone, radical shortening of the abundance of the main commercial fish species, the introduction of the food competitors caused significant disproportion in the ecological pyramid (**Fig.** 60). All this led to the growing unbalance of the food chains and to the extreme form of the trophic interrelations-the excessive cannibalism.

For instance, the forage spectrum of the Barents Sea cod includes 200 species of organisms and 20 among them are of primary importance. Being omnivorous, cod prefers capelin, herring, polar cod, the young haddock. Current deficiency of capelin in the diet of cod led quite naturally to the eating out of the young cod (Karamushko and Karamushko 1995). In addition, eating out of the young cod by other predators – long rough dab, spiny skate, harp seal, minke whale – increased in 1992–1998 (**Fig.** 61).

In many mass Barents Sea birds species the increased cannibalism and a sharp lowering of the recruitment of the abundance is also observed (Krasnov et al. 1995). This phenomenon was a consequence of deficiency of forage of fish. (Fig. 62, 63). It is known that every sea gull female, as well as other bird species female, needs 200–400g of small fish daily during feeding period.

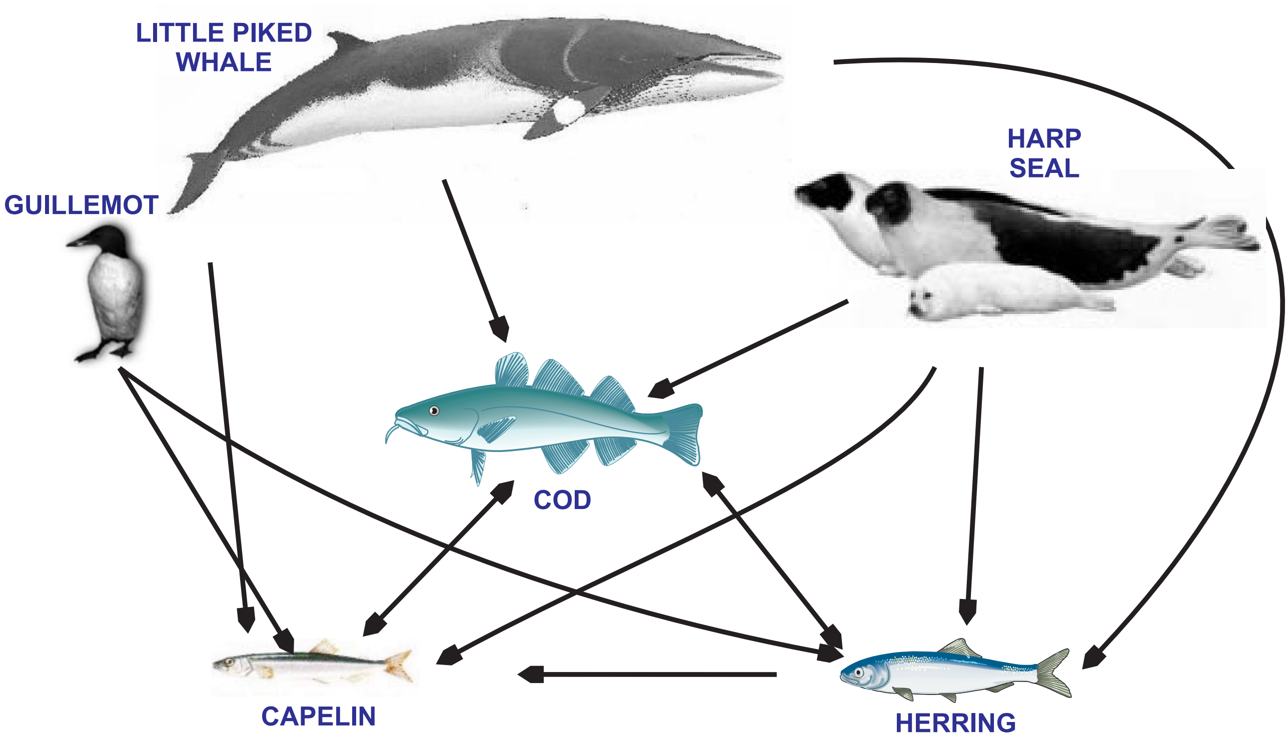


Fig. 60. Inter-specific interrelations in the Barents Sea ecosystem

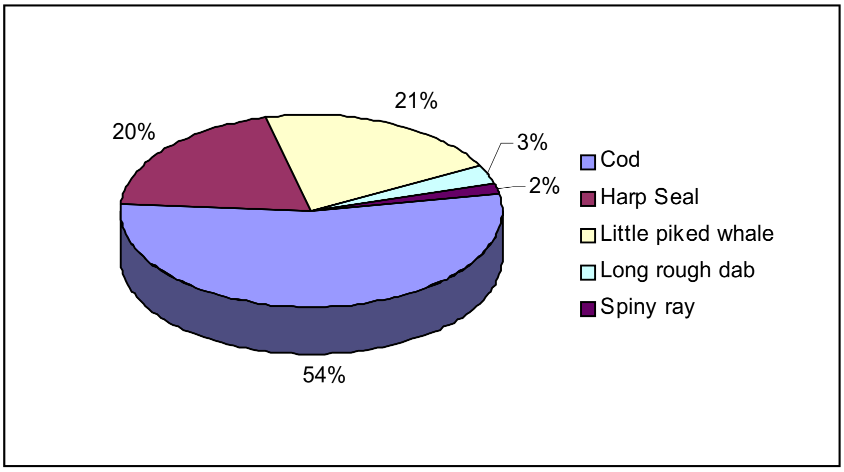


Fig. 61. Ratio of young cod consumption by different predators in 1994-1996 (by PINRO data)

In the southern seas the expansion of different exotics significantly disrupted the natural food chains. The food deficiency during the common kilka and anchovy (sprat species) feeding migrations influenced negatively the fatness, size-weight composition and other qualitative indices of the fishes. Decrease of the common kilka and anchovy abundance in connection with the competition of the comb jelly resulted in the increase of natural mortality of their main predator – zander. As the result, the multigenerational structure (up to 15 generations) the Azov Sea zander population was destroyed (Kukarina 1995).

I - Ainovy Islands
II - Seven Islands Archipelago

Index	Puffin		Herring gull		Great black-backed gull	
	I	II	I	II	I	II
Herring	25.4	16.0	32.7	14.3	40.6	23.7
Capelin	12.7	17.0	3.8	10.2	—	9.8
Sand eel	5.4	46.0	—	—	3.1	4.6
Cod	—	2.0	5.8	18.6	31.2	30.9
Number of stomachs examined	55	100	52	322	32	194

Seven Islands archipelago

Index	Thick-billed murre	Atlantic murre	Razorbill	Puffin	Black guillemot
Herring	27.0	24.0	37.7	16.0	12.5
Capelin	12.6	18.7	21.7	17.0	7.2
Sand eel	16.2	19.7	33.3	46.0	17.0
Cod	14.4	22.1	11.6	2.0	25.0
Goby	—	—	—	—	5.7
Gunnel	—	—	—	—	10.2
Number of stomachs	111	208	69	100	— 88

Fig. 62. Absolute occurrence (%) of the mass fish species in the forage of the colonial birds on the Ainovy Islands and on the Seven Islands archipelago (by Belopolsky 1971)

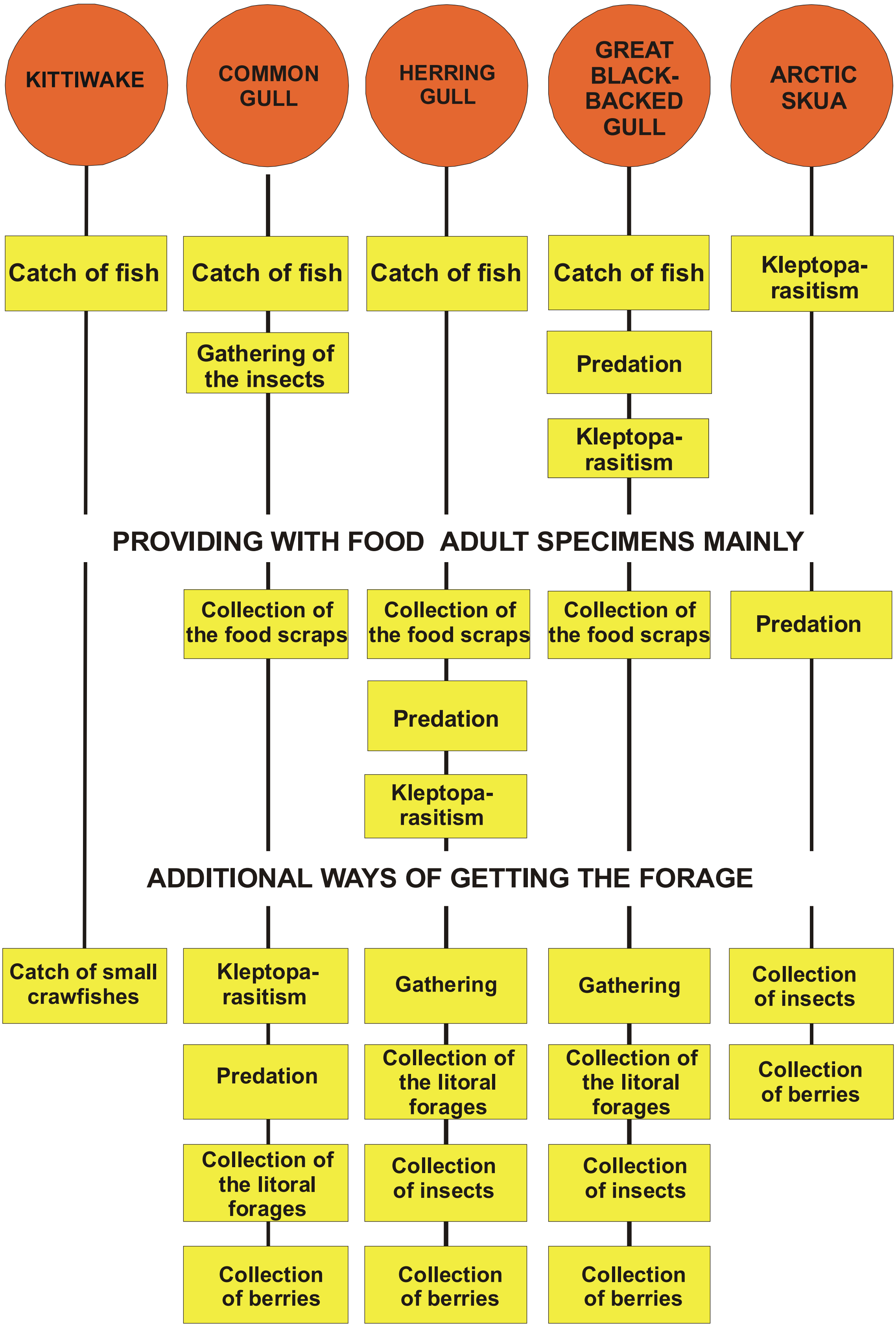


Fig. 63. Ways of obtaining forage by the sea gulls in the conditions of the Seven Islands archipelago in 1978-1987 (by Krasnov et al. 1995)

BIOENERGETIC UNBALANCE

Distortion of the population structure in the marine communities causes shifts in the character of biochemical processes in the ecosystems. The biogene elements inflow into the sea in the areas of colonial birds species nesting, mass spawning of both bottom and pelagic fish species, feeding migrations of small whales, lay out and reproduction of seals decreases. The natural way and the productivity value of all the links of the food chain in the marine ecosystem becomes broken (Fig. 64, 66).

The question is about a complete disappearance of the feedback process . For instance recently capelin when the biomass of the mature part of its population was 3–4 mln ton delivered into the water during spawning about 55,200 t (dry mass) of the organic matter (Timofeev 1988). 10 fold capelin population decrease and, consequently, reduction of its reproductive product and seminal fluid production, might cause significant disturbances in the natural cycles of the planktonic communities productivity.

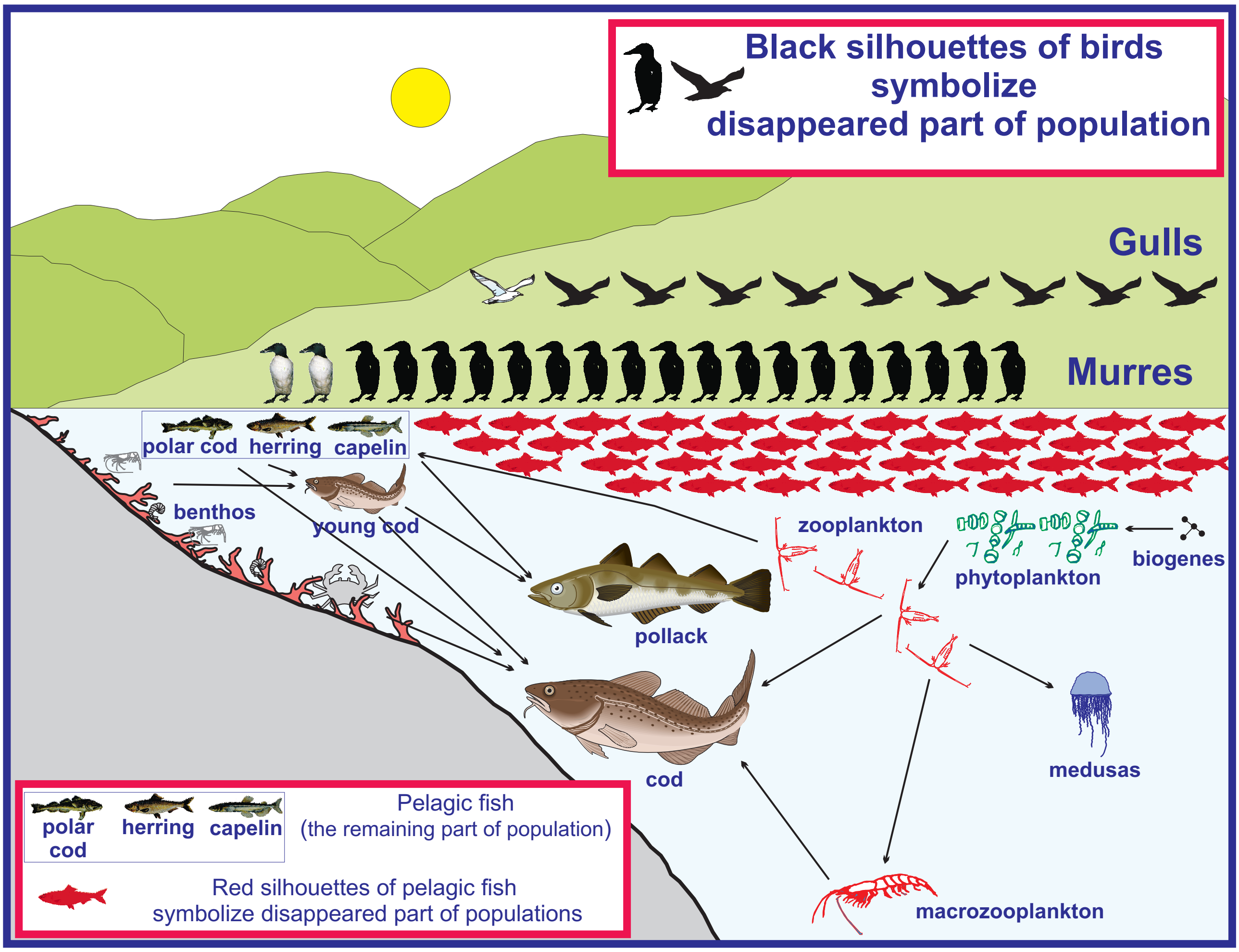


Fig.64. Scheme of bird colonies degradation in connection with the disruption of food interrelations

BREAKAGE OF THE HOST-PARASITE INTERRELATIONS

Regulatory function of the parasite fauna in the biological processes is well-known (**Fig.** 65). For the Barents Sea ecosystem the breakage of the connection parasite-host as the result of an almost complete catch out of the polar cod may serve a typical example . This mass fish species the catches of which in 1971 reached 330,000 t served as the main link of the energy transfer in the animals world within the vast areas around the Novaya Zemlya, the Vaigach Island, the Franz Josef Land – that is on the area on the boundary between the Kara and the Barents Seas. This ecological place of polar cod is clearly seen on the example of its parasite fauna which served as the main catalyst for the helminthes (35 species) circulation. Polar cod was the key element of the trophoparasite chain of the Arctic basin biota (Karasev 1988).

As it is known in the Azov Sea in the 1960–70s, 30% of zander at the age of 3 years was affected by the parasite (ligula of the *Blockh* genus) (Troitsky 1973). As a result of the sharp decrease of the young zander reserves, which is the main food item of the ihchthyophagous populations of waterfowl (the main host of the parasites), not only disrupted the normal reproduction of the European cormorant and other birds species, but quite probably led to the destruction of the natural host-parasite interrelations. And this, in its turn, may cause serious consequences for the whole Azov Sea ecosystem.

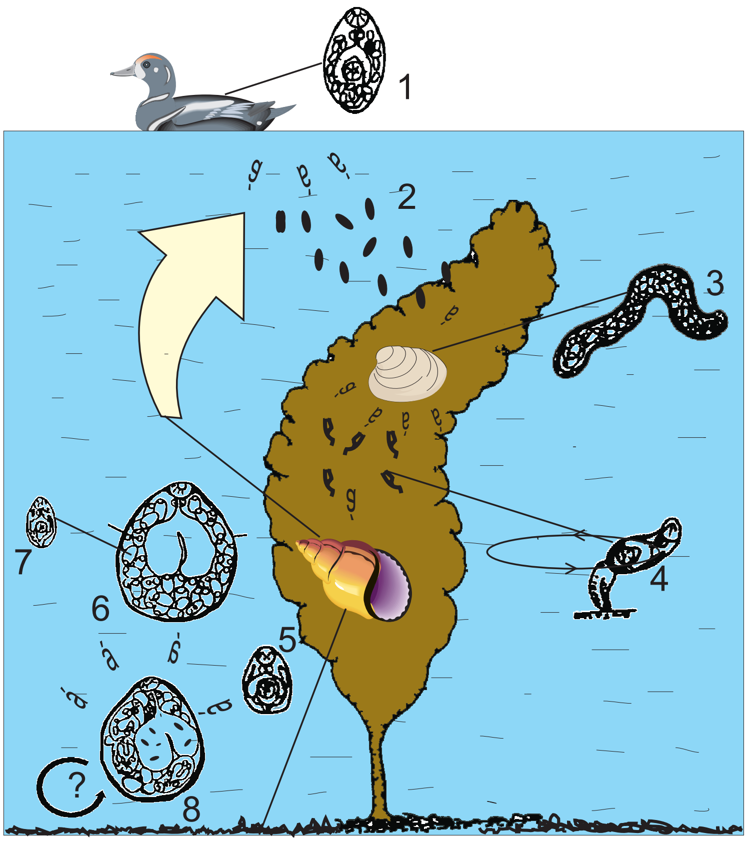


Fig.65. Parvatrema sp. life cycle (by Galaktionov 1996)

a) marita in the stomach of the common eider; b) the egg with miracidium; c) the daughter sporocyst in the bivalve mollusk Turtonya minyta (the first intermediate host); d) cercarea; e),g) the stages of development in the prosobranch mollusk; f) the young metacercarea of the first parthenogenetic generation; g) metacercarea of the second parthenogenetic generation containing the invasion for the final metacercareas host

EUTROPHICATION OF ESTUARIES AND SHELF SHALLOWS

A sharp increase in the 1970–90s of the municipal and industrial sewerage with a high concentration of biogene elements and a wash out of the fertilizers from the agricultural fields became the reason of the unprecedented sharp outbursts of the microalgae development and an extremely high level of primary production. Eutrophication manifests itself in the development of the oxygen deficiency in the water layers near bottom, in the «water blossom» due to the intensive development of phytoplankton during the vegetation peak and in the species diversity lowering. These phenomena are especially typical of the shallow-water areas of the southern seas. They lead to the mass die off due to oxygen deficiency and a sharp decrease of the abundance of both commercial species and their food items.

In the Azov Sea a constant increase of the amount of the organic compounds which strengthened especially after the regulation of the river run-off caused mass deaths almost every year. For the period 1960–1980, the area with hydrogen sulphide contamination of the near bottom layers was in average of the order of 99,000 km^2, or 60–70% of sea (Bronfman et al. 1979; Bronfman and Khlebnikov 1985). As the result of the hydrogen sulphide impact, bottom and near bottom fauna died, including fishes (the gobies, mainly). Already the first storm mixed the water and eliminated the mortality phenomenon, however the restoration of the perished fauna takes more time.

INCREASE OF THE QUANTITY OF PELAGIC CRUSTACEANS

Abnormal increase of the pelagic crawfishes at the predation pressure loosening became typical for the primary links of the marine ecosystem. On some sites their biomass reaches 50–80 kg/m^3. After the destruction of whales in the marine waters of the Antarctic, krill biomass reached an enormous value of about 600 mln t. This is much more than the total weight of all people inhabiting the Earth. At the moment due to the similar reasons the Barents Sea crawfishes (calanus, euphausiids, amphipods -hyperiids) are not utilized (Fomin 1995). The value of under-exploited food might reach probably 50–60 mln t.

In the Black Sea simultaneously with the growth of biomass and the changes of the phytoplankton structure similar phenomena take place in the zooplankton populations. Its total biomass in the north- west part of the Black Sea became 10 times as much in the period from 1960 till 1981. And the specific weight of the *Nocticula* increased from 40 till 80% and its biomass by 15 times. And at the same time several species of the forage zooplankton – *Cladocera* crawfishes, *Hyponeiston pontelids* (Zaitsev 1992).

Thus, in the present situation, large amount of the production of the lower trophic levels is not exploited, which leads to the decrease of biological productivity of the water reservoirs as a whole. Thus, the so-called «biological contamination» of seas started to develop.

DECREASE OF THE NATURAL REPRODUCTION OF THE ABORIGINAL BIOTA

One of the most important factors of preserving the abundance and diversity of the aboriginal biota species is support of the reproductive function of the populations. The fact that the main components of the fauna have different reproduction cycles makes the marine systems more complicated. For instance, the sturgeon do not spawn every year. They spawn at the age of

10–18 years and the intervals between spawning vary greatly; they are approximately 4–5 years long. Many species of marine mammals do not breed annually. On the other hand, the key fish species in the ecosystem spawn annually (cod, salmon) or 1–2 times during their life cycle (capelin, humpback salmon).

Any breakage of the ecological balance, and high fishing mortality, degradation of the spawning grounds, deficiency of forage in particular, diminish the scale of natural restoration. At the moment, almost all the valuable fish species inhabiting both the northern and the southern seas are subjected to this process. For this reason the majority of commercial fish species have a quicker maturation rate, whereas maximum and average length of fishes in the population became smaller, the rejuvenation of the age composition took place in the populations, their growth rate became quicker.

Pelagic short-lived fish species are the most vulnerable. Natural cycles are typical of their reproduction. If cycles of poor productivity and fishery pressure coincide in time the collapse of the population takes place. Dramatic events of almost complete disappearance of the population of the Barents Sea capelin, Atlantic herring, polar cod might serve as examples of such collapse (Matishov and Pavlova 1990, Matishov 1992, Alekseev and Ponomarenko 1997).

The reason of the catastrophic decreasing of the Barents Sea birds colonies was the deficiency of the forage due to the over- fishing of low-valuable fish species. A typical example of the 8 fold decrease of natural restoration and the abundance of guillemots occurred on the Bear Island (Fig. 66).

The extreme forms of lowering of the natural reproduction of fishes in the second half of the 20th century became typical of the southern seas. After damming of many anadromous and semi-anadromous fishes passages to the majority of spawning grounds already by the end of the 1980s, for instance in the Azov Sea, industrial fish farming began to play the leading role in the increase of the sturgeons, zander and bream populations (Ivanchenko 1997, Rekov 1998, Kovtun et al. 1998). Industrial restoration provided almost 100% of the reserves of white (great) sturgeon, more that 90% of starred sturgeon and 80% of sturgeon. The specialists of the *Azov Fishery scientific-research institute* came to the reasonable conclusion that the irreversible processes take place in the restoration mechanism, which lead to fading away of the natural reproduction of the sturgeons.

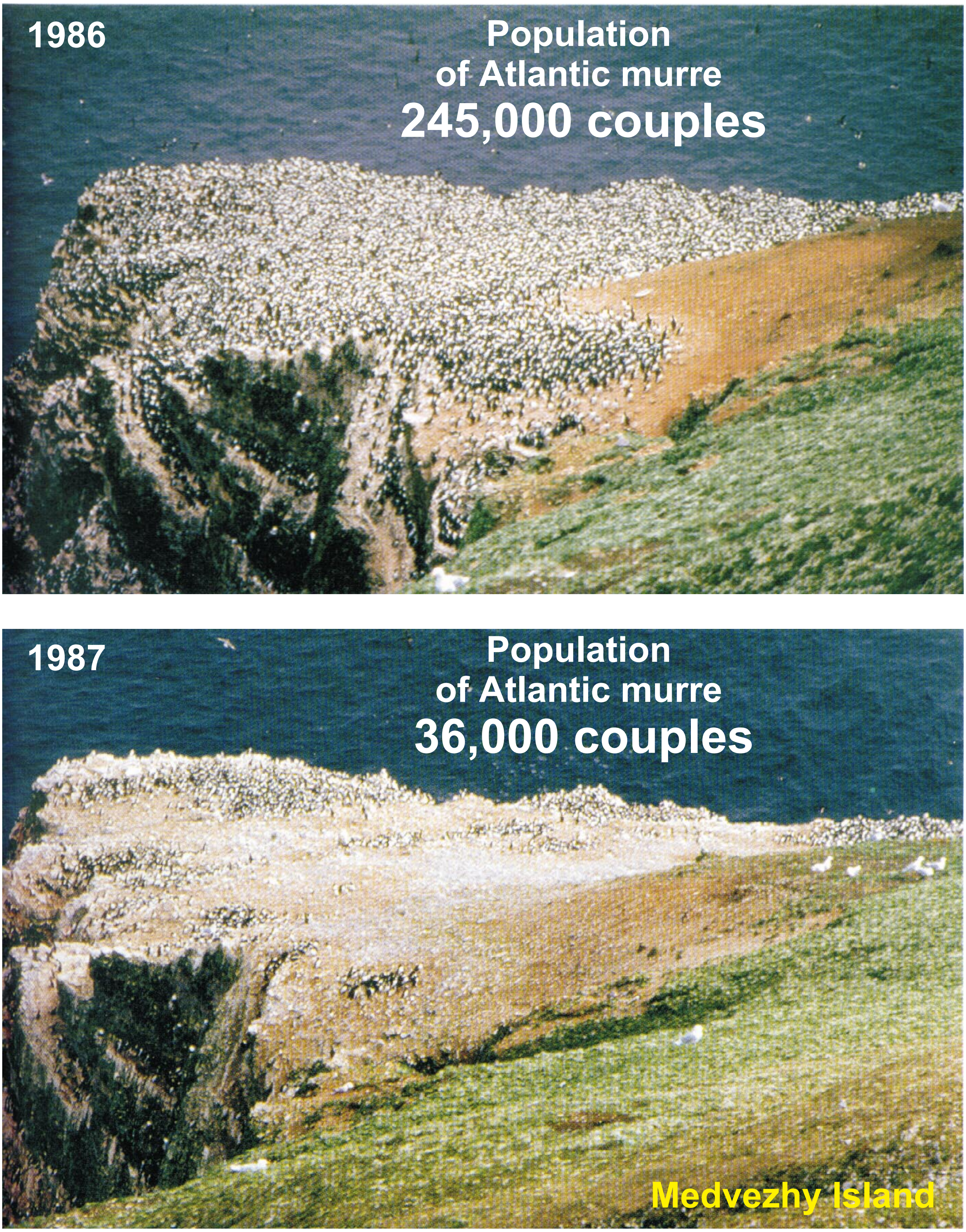


Fig. 66. Consequences of the capelin population collapse impact on the bird colonies (by The State of the European Arctic 1996)

POSSIBLE WAYS OF STABILIZATION OF THE COMMERCIAL RESOURCES OF THE SEA

IMPROVEMENT OF FISHERY REGULATION MEASURES

The key problem of supporting biodiversity is preserving the reproductive properties of marine animals populations . Taking into consideration a high artificial mortality of fish fauna, a more flexible system of temporal limitations for the fishery during the spawning season is needed. For instance, the introduction of the ban of fishery of cod spawning at the Norwegian coasts might strengthen the Barents Sea part of the population. Ban on the hunt for the white coat (belek) of the harp seal will produce an analogous effect.

In spite of the progress of the population models the scientists are confronted with large uncertainties in the estimations of the allowable catches (Maximum Allowable Catch). While previously the consequences of withdrawal of some sea species for other species normally were not considered at the estimation of the commercial species MAC, such an approach is unacceptable for the sustainable fishery model.

But none the less even current models of calculations and forecasting of the reserves have significant deficiencies. For instance, they do not consider the inter- specific interrelations in the ecosystems and the influence of the environmental conditions on the dynamics of abundance and biomass of exploited populations (Borisov 1998, Kochikov 1998). As the result the estimation of the reserves and, moreover MAC forecasting, precision and reliability of the developed recommendations do not often meet the requirements of the preserving of water bioresources and their rational exploitation. It should be pointed out that from the point of view of science the probability factor will remain the integral attribute of fishery oceanography forecasts. Much has been said about it at the International Congress in Bergen (Norway, June 1997) and at the first congress of ichthyologists of Russia in Astrakhan (September 1997). A stable usage of bioresources demands the transition to the ecosystematic principles of management. It is important to limit the fishery of the short-lived fish species, to apply a flexible system of temporal limitations for fishery during spawning, to introduce ecologically safe gears, etc.

SHIFT OF FISHERY TO THE NON-TRADITIONAL BIORESOURCES

Biological resources of the seas are very diverse but inefficiently utilized (**Fig.** 67). Some species, for instance, cod and haddock are subjected to a strong fishery pressure, while different species of flounder, polar shark, catfish, red fish, polar cod and other fish species and mollusks, as well as algae, are still exploited on the minor scale. The abundance of these species in the Barents Sea is rather significant, which implies that they may become objects of fishery.

ORGANISMS	BIOMASS, thousand tons
Macrophytes (algae) - laminarias - fucoids - all	 415 180 about 600
Euphasiides (sand hopper, polar krill)	40 000
Mussel	300
Scallop	1 000
Modiolus	200
Sea urchins (total number for all species)	2,000-3,000
Sea cucumber	350

Fig. 67. Total biomass of several algae and invertebrates species in the Barents Sea (by the data of Makarov V. N., Drobysheva S. S., Denisenko S. G., Gudimova E. N.)

LIMITATION OF THE MECHANICAL IMPACTS ON THE LIVING BENTHIC COMMUNITIES

Some commercial practices are known to produce a negative impact on benthic communities. Trawling of fish and invertebrates and dredging of shallow water navigation canals are regarded as the most important of them.

It would be hardly feasible to abandon practice of harvesting the mollusks with drags on the ships of the «Scalloper» type or to stop using bottom trawls on the Barents and the Baltic Sea cod, the Azov Sea gobies, the Black Sea flounder. But to continue the practice of «replowing» the sea bottom and hauling on board several tens of kilos to several tons of benthic organisms after each gear deployment means to undermine deliberately the forage basis of the commercial fish species.

It is quite evident, that the national shelf fishery should start using the new types of trawls to preserve bottom ecosystems. The experience of the Norwegians and the Japanese will be useful in this respect, as they deploy bottom friendly trawls and bottom long-lines.

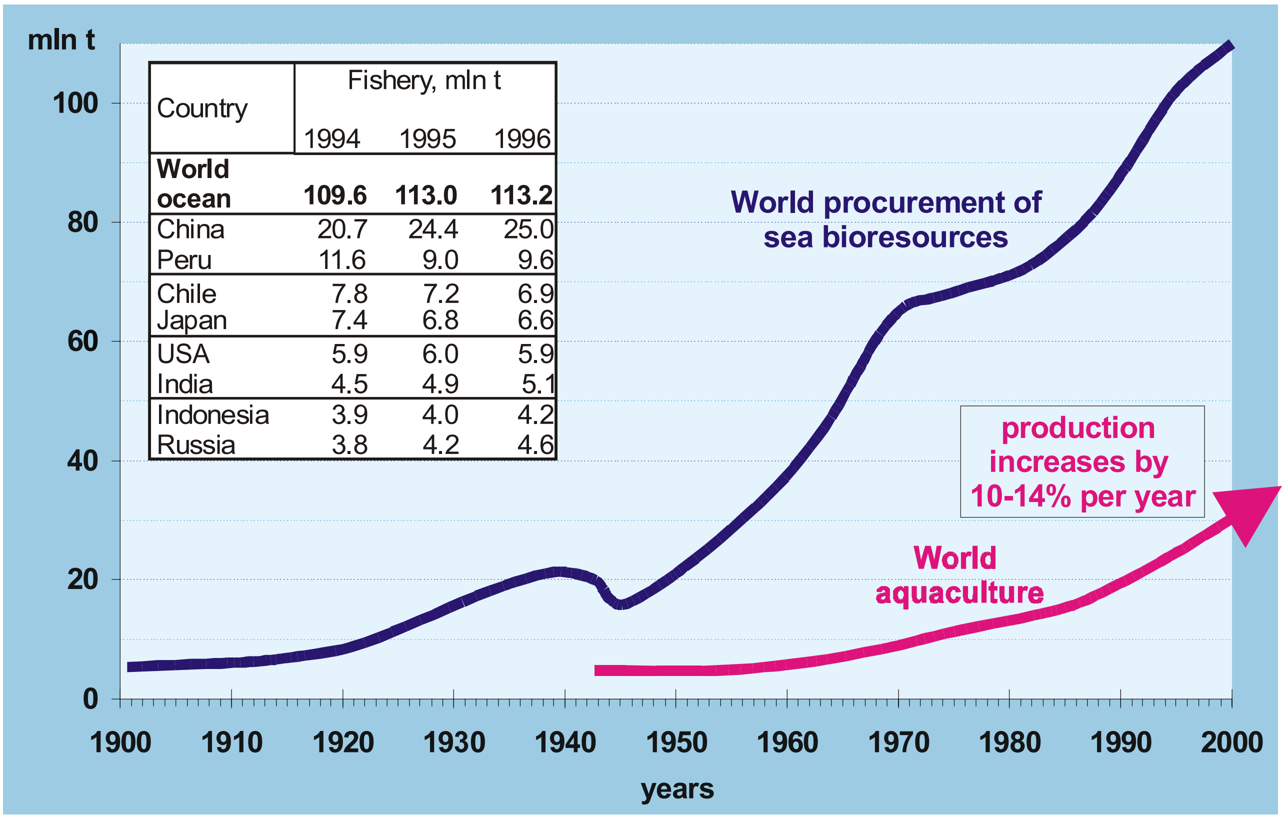
To minimize the negative consequences of dredging 2 ways of action can be adopted: (1) to introduce the full ban on works during the fishes brood period and (2) to select ecologically safe ground dumping sites.

ARTIFICIAL REARING (RESTORATION)

Different modes of aqua- and marine culture are well developed branch of the World Fishery. (**Fig.** 68). It is especially typical of the regions with a warm maritime climate. The production of world aqua-culture exceeds 25 mln tons. It includes rearing of fishes, (49.5%), algae (28%), mollusks (18.2%). The international experience in marine culture should not be followed blindly, of course.

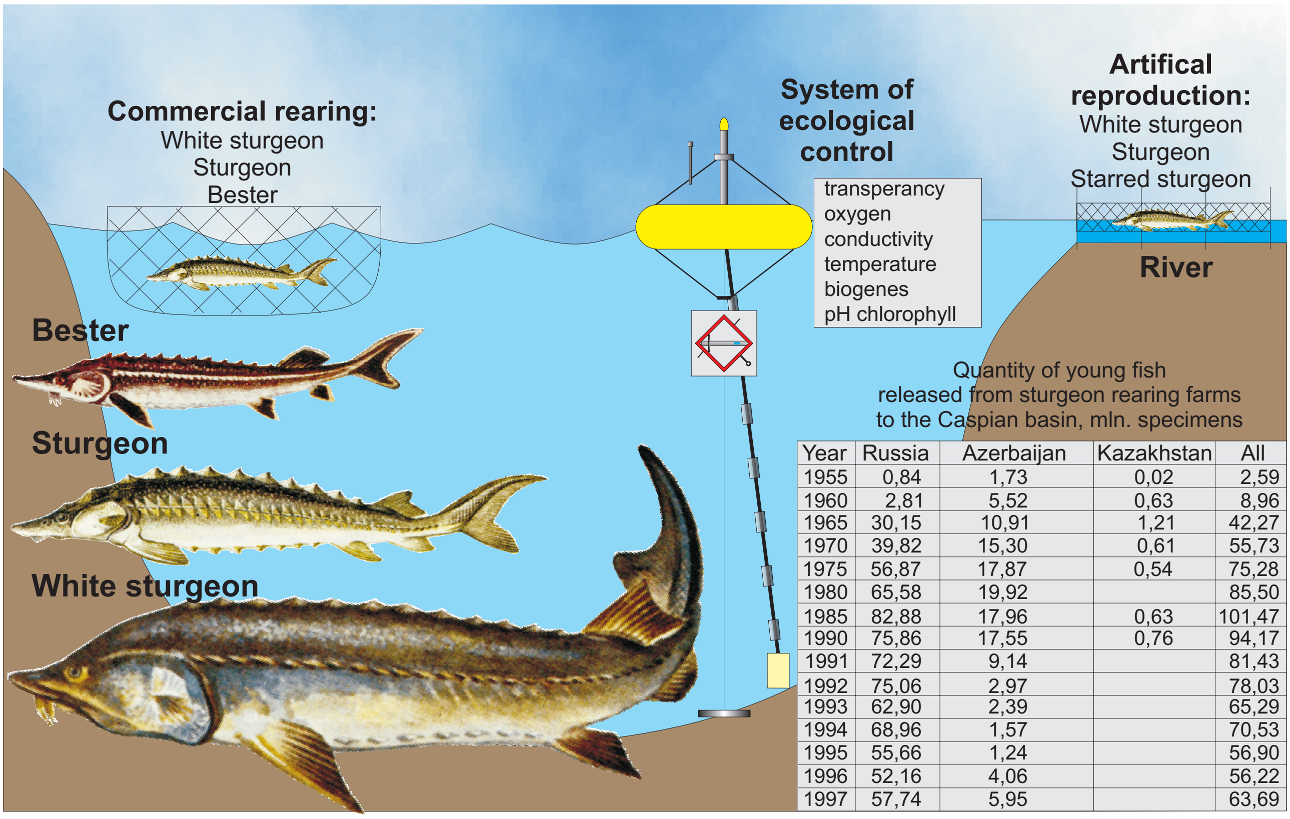
The achievements in the sphere of procurement of large amounts of viable planting material (eggs, larvae, young fish), rational diet, genetics, selection, development of the effective means of treatment of the diseases , technical innovations in the establishing of the marine and land constructions fostered the progress of marine culture(Dushkina and Esipova 1997).

In the present situation a sturgeon rearing farm is the most perspective direction of fishery especially for Russia (**Fig.** 69). Realization of reproduction measures, offered several times by the *Azov Fishery scientific-research institute*, will allow to increase the catch of only the sturgeon in the Azov Sea basin to 15,000 t (Gorbacheva and Rekov 1996). But the artificial rearing is not regarded as alternative to natural reproduction of the sturgeon. Owing to the species biological peculiarities the sturgeon is the easiest object of rearing and has been released in large amounts since the 1950s by fish farms on the Don and later the Kuban River.



Country	Fishery, mln t 1994	1995	1996
World ocean	**109.6**	**113.0**	**113.2**
China	20.7	24.4	25.0
Peru	11.6	9.0	9.6
Chile	7.8	7.2	6.9
Japan	7.4	6.8	6.6
USA	5.9	6.0	5.9
India	4.5	4.9	5.1
Indonesia	3.9	4.0	4.2
Russia	3.8	4.2	4.6

Fig. 68. Dynamics of the economic exploitation of hydrobioresources in seas and oceans



Year	Russia	Azerbaijan	Kazakhstan	All
1955	0,84	1,73	0,02	2,59
1960	2,81	5,52	0,63	8,96
1965	30,15	10,91	1,21	42,27
1970	39,82	15,30	0,61	55,73
1975	56,87	17,87	0,54	75,28
1980	65,58	19,92		85,50
1985	82,88	17,96	0,63	101,47
1990	75,86	17,55	0,76	94,17
1991	72,29	9,14		81,43
1992	75,06	2,97		78,03
1993	62,90	2,39		65,29
1994	68,96	1,57		70,53
1995	55,66	1,24		56,90
1996	52,16	4,06		56,22
1997	57,74	5,95		63,69

Fig. 69. Organization of sturgeon commercial rearing and increase of their reproduction rate in the Caspian Sea basin and in the Azov Sea and the Black Sea basins

Till the middle of 1980s, the catch of sturgeon reached practically maximum average annual catch of the 1930s – 1,000 t, and more than 90% of the catch were the fishes released from the fish farms. A the same time, recruitment of starred and white sturgeon was far from being sufficient (Makarov and Rekov 1997).

Marine culture in the Western Europe is concentrated in the gulfs and fjords (**Fig.** 70). Norway rears on the farms up to 0.4–0.5 mln t salmon. For some reason or other, efficiency of the artificial salmon rearing in the Murmansk region is still very low.

Marine culture development plans for Russia must be elaborated with regard of the ecosystem interrelations so as not to disturb their mechanisms. In such a case the efforts should be focused on restoration of the aboriginal fauna species. The scientific background of organizing of commercial species artificial rearing are to be based on the knowledge of the principles of functioning of all links of marine ecosystems and trophic chains (interrelations).

Most competitive branches of aquaculture should be primarily developed. Consequently investments should be made into sturgeons rearing (**Fig.** 69). The most substantial share of investments may be received as compensations, if oil and gas procurement on the Russian shelf will be as civilized as in the United Kingdom and Norway.

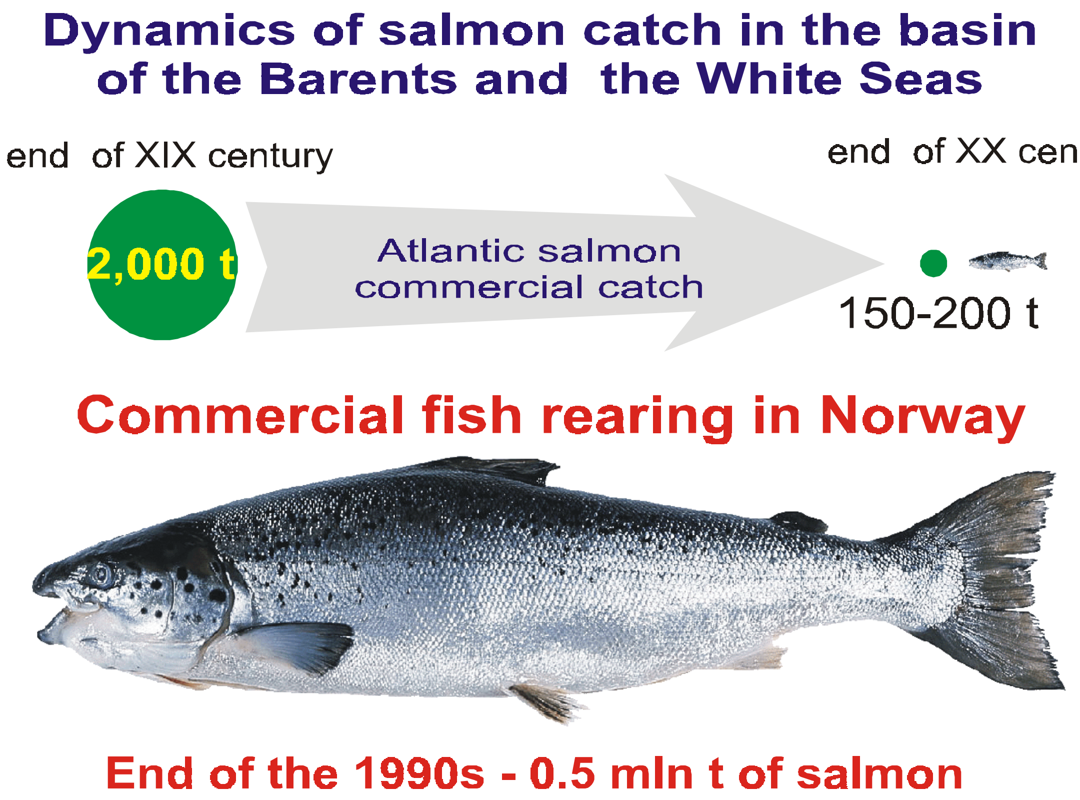


Fig. 70. Perspective development of fisheries

STATE SUPPORT OF FISHERY

Today the problems of stable development of fishery in the Russian seas are as acute as never before. In the new social and economic situation it is extremely hazardous to continue to carry out traditional extensive mode of fishing. A well balanced national strategy of fishery development, which takes into account possible extinction of the contemporary exploited resources, is needed. The main principles of this strategy might be as follows: ecosystematic, economic, infra-structural, administrative, psychological, juridical, professional, etc. These principles might be implemented provided all the sides are interested: authorities, fishermen, investors, scientists and consumers.

A series of measures should be implemented including the state support of fishery (subsidies), restoration of control over this branch of industry, broadening of the spectrum of the harvested resources, combining efforts of both the fundamental and applied science with special emphasis on studies of genetics, selection, adaptation of marine animals to the changing conditions of the environment.

Special attention should be paid to the compensating development of aquaculture. The Southern basins (the Azov Sea, the northern part of the Caspian Sea) might be re-profiled as «big cage» for the full cycle artificial rearing of the valuable fish species from fish eggs to fish of commercial value. Under the less favorable conditions (the Barents Sea) the artificial rearing of the young with a subsequent development of fishes in the natural environment is possible. Development of the sea farming should be supported by the state.

MEASURES FOR PRESERVING EQUILIBRIUM IN MARINE ECOSYSTEMS

The main strategy of the nature protection in the world is a progressive development and introduction of ecologically clean technologies into all the spheres of industry and human activities. This will result in radical reduction of the inflow of harmful substances into the estuaries and marine ecosystems. Large scale realization of this principle requires heavy investments which, nowadays, Russia could not afford. That is why only several realistic and practical ways are presented.

EXPERTISE OF THE ECONOMIC ACTIVITY AT SEA

All kinds of economic activity at sea affecting the life of ecosystems, including fishery, must undergo Environmental Impact Assessment (EIA) procedure. The EIA practice of the oil-gas complex on the shelf and ports construction may serve as the example.

RESTORATION OF THE SYSTEM OF THE STATE ECOLOGICAL MONITORING AT SEAS

At the moment, marine monitoring is practically non-existent. Biological and ecotoxicological monitoring is especially important as it gives the quantitative basis for decision making on the sustainable exploitation and sanation of natural ecosystems. That is why the restoration of the system of the state monitoring of marine environment and biota using remote sensing and autonomous buoy stations is of crucial. This is especially important in connection with the perspective of gas-oil extraction on the shelf (**Fig.** 71). Monitoring will allow to reduce the existing degree of uncertainty in ecosystem planning and decision making. The concept of the assimilation capacity developed by Academician Yu.A. Iisrael may become the basis for the objective quantitative estimations of the Maximum Allowable Coefficient of pollutants in different marine systems.

REGULATION OF THE RIVER WATERS RUN-OFF

In current ecological situation the state regulation of the regime and the volume of the river run-off in accordance with biological calendar is needed. This calendar must consider the seasonal life cycles of the marine flora and fauna in a certain sea basin. The specialists recommend to provide passage for the spawners into the upper part of the rivers in spring to increase effectiveness of natural reproduction and prevent large fluctuations of the water run-off through the hydro engineering constructions during mass migrations. It is also necessary to maintain water flow regime of the spawning grounds as close to natural as possible.

Specialists of the *Azov Fishery scientific-research institute* found out, that the river water run-off of no less than 35–36 km^3/year (including 17–18 km^3/ year spring run-off) is required to maintain the Azov Sea ecosystem at the present level. At the moment, this rich shallow water reservoir almost lost the capability of self purification and withstanding the excessive anthropogenic pressure. Such artificial measures to restore the Caspian Sea and the Azov Sea regime as, for instance, the transportation of the waters of the northern rivers or the dam construction across the Kerch Strait are unacceptable from the point of view of the modern science.

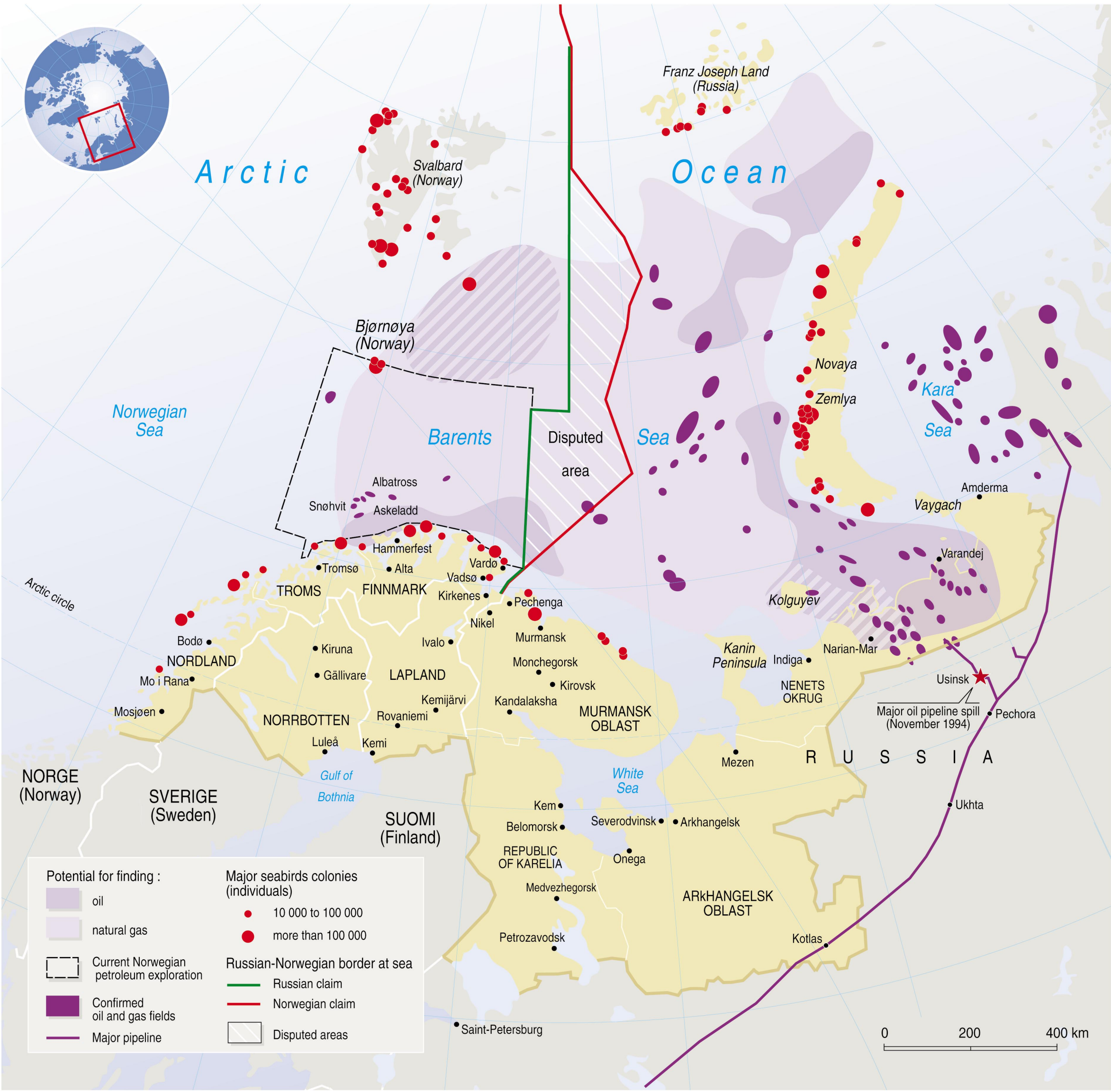


Fig. 71. Potential danger of oil and gas fields for the Barents Sea biota (Barents watch 1998)

It is evident that further development of the economy of the south of Russia is to be balanced considering the restoration of the unique ecosystem of the Azov Sea basin. A new international aspect of the problem caused by the disintegration of the USSR has to be considered, too

BIOLOGICAL AND MECHANICAL SANATION OF PORT AREAS AND APPROACH CANALS IN THE AZOV SEA, NORTH OF THE CASPIAN SEA AND THE GULF OF FINLAND

The examples of successful restoration of the degraded communities are numerous. The experience and the restoration technologies of the Great Lakes and the Chesapeake Bay in the USA, the Thames and the Rhine rivers in Europe should be utilized. For instance, artificial reefs which serve as the substrates for the bottom organisms-filters of contamination have been used in the West for quite a long time.

There is positive experience of development of water purification biotechnologies in the coastal zone in Russia (Shevchenko et al. 1987). Erected constructions are quite quickly inhabited by the thick water vegetation. Besides such animal periphyton as water mollusks and other filtrators frequently occur there. Positive reef reclamation will allow to improve significantly the water environment necessary for the support of a high biological and balneological status of the Azov Sea and the Baltic Sea.

Bottom sediments at the ports and the approach canals should undergo mechanical purification. As a rule, they comprise 50–80% of finely dispersed silt fractions contaminated with the oil hydrocarbons, heavy metals, polycyclic aromatic hydrocarbons, pesticides. The purification process should be carried out alongside regular bottom dredging works in the areas of drifts in the access canals. The volume of sediments annually transferred from the bottom of the Azov Sea (approximately 3.6 mln t) exceeds the Don River input of hard matter (1.2 mln t).

SANITARY AND TECHNOLOGICAL CONTROL AND ECOLOGICAL STANDARDIZATION

The problem of preventing unintentional biological and chemical contamination of water reservoirs is evident at the moment. It is connected with out-of-date technologies and non-compliance with ecological regulations in general.

Any modes of uncontrolled introduction of exotics should be stopped. It concerns, e.g. import of exotic species with ship ballast waters or in the course of introduction of new species of fish, crustaceans and mollusks. Improvement of epidemiological control over reproduction conditions of valuable fish species is of no less importance. Salmon, sturgeons, trout, carps fish farms are known to be periodically affected by mass outbursts of different diseases.

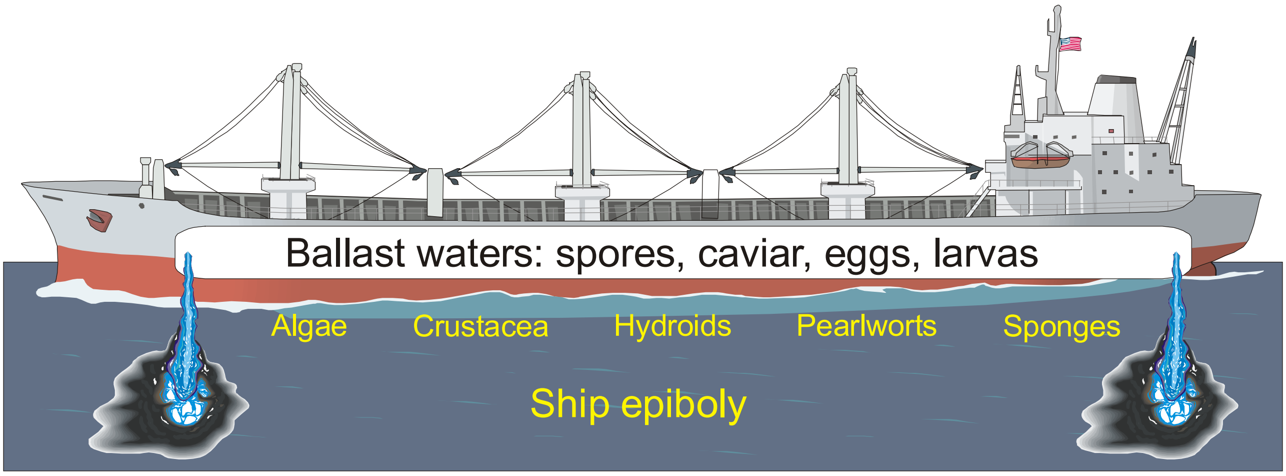
It is necessary to further develop ecotoxicological criteria and Maximum Allowable Coefficients values with regard of international experience. At the moment, these standards are practically undeveloped for different types of marine basins and climatic conditions. Both underestimation of the danger of chemical contamination and reconsidering of its impact are equally important.

It is understood, that in the closed shallow-water Azov Sea and the vast open basin of the Barents Sea the effect of the said processes will be quite different. Undifferentiated approach to the standardization of the anthropogenic pressure when implementing the marine commercial ecosystems protection measures might lead either to the discrediting of useful ideas and methods or countless economic losses.

INFLUENCE OF THE EXOTICS DANGEROUS FOR THE ABORIGINAL FAUNA

As it has been already noted, several hundreds species of the alien fauna penetrated into the European seas of Russia from different parts of the World ocean (**Fig.** 72). The exotics have penetrated by 2 ways: either intentionally or accidentally.

Generally, this evolutionary process proceeds in the marine ecosystems latently, so to say, unseen from outside. New exotics are being constantly discovered during marine biological expeditions of *MMBI, ZIS, IO RAS, PINRO, AzSRIF, IBSS, YugNIRO, AtlantNIRO, MSU, RSU*. Due to a high degree of adaptability they have acclimatized and now they reproduce and may threaten to the well-being of the aboriginal fauna.



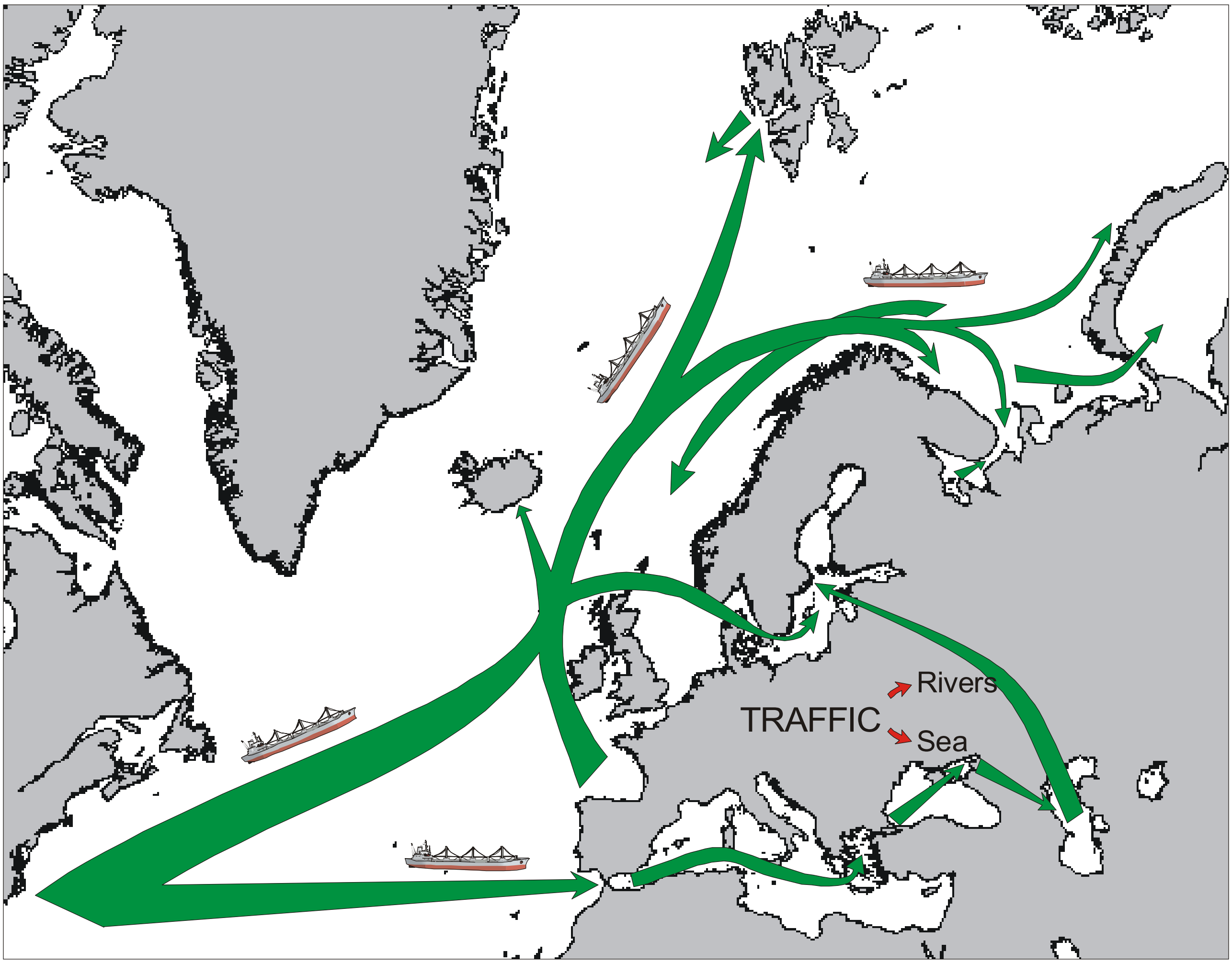


Fig. 72. Settling of the exotic fauna via transcontinental transportation by sea ships

However, a significant part of the exotic species actually upsets and, in some cases, suppresses the natural functioning of marine ecosystems. The humpback salmon introduced into the rivers of the Kola peninsula constantly ousts the Atlantic salmon from its spawning grounds. Almost half a million population of the Kamchatka crab in the coastal zone of the Barents Sea successfully competes with the aboriginal fauna for the same forage.

The Caspian crawfish *Cercopagis,* which settled down in the Gulf of Finland, spreads in the Baltic Sea and step by step occupies the niche of such valuable fish species as sprat and kilka (Avinsky 1997).

Gray mullet and stone moroco gradually supersede local valuable fish species in their natural ecological niches in the Azov Sea.

In the 1980–90s, the outburst of the abundance of comb jelly – the East American waters species (**Fig.** 73) – turned out to be quite a calamity for the Black Sea and the Azov Sea basin. During some years its biomass equaled 1 bln t in the Black Sea, that in the Azov Sea reached 20–32 mln t (Volovik et al. 1996, Zaitsev 1998). It should be noted for comparison's sake that the total biomass of the pelagic fish species – anchovy (European anchovy) and the common kilka – before the introduction of its main competitor for food was several million tons. For the subsequent years in future the forecast volume of formerly mass fish species is 7,500 t (Borisov 1998).

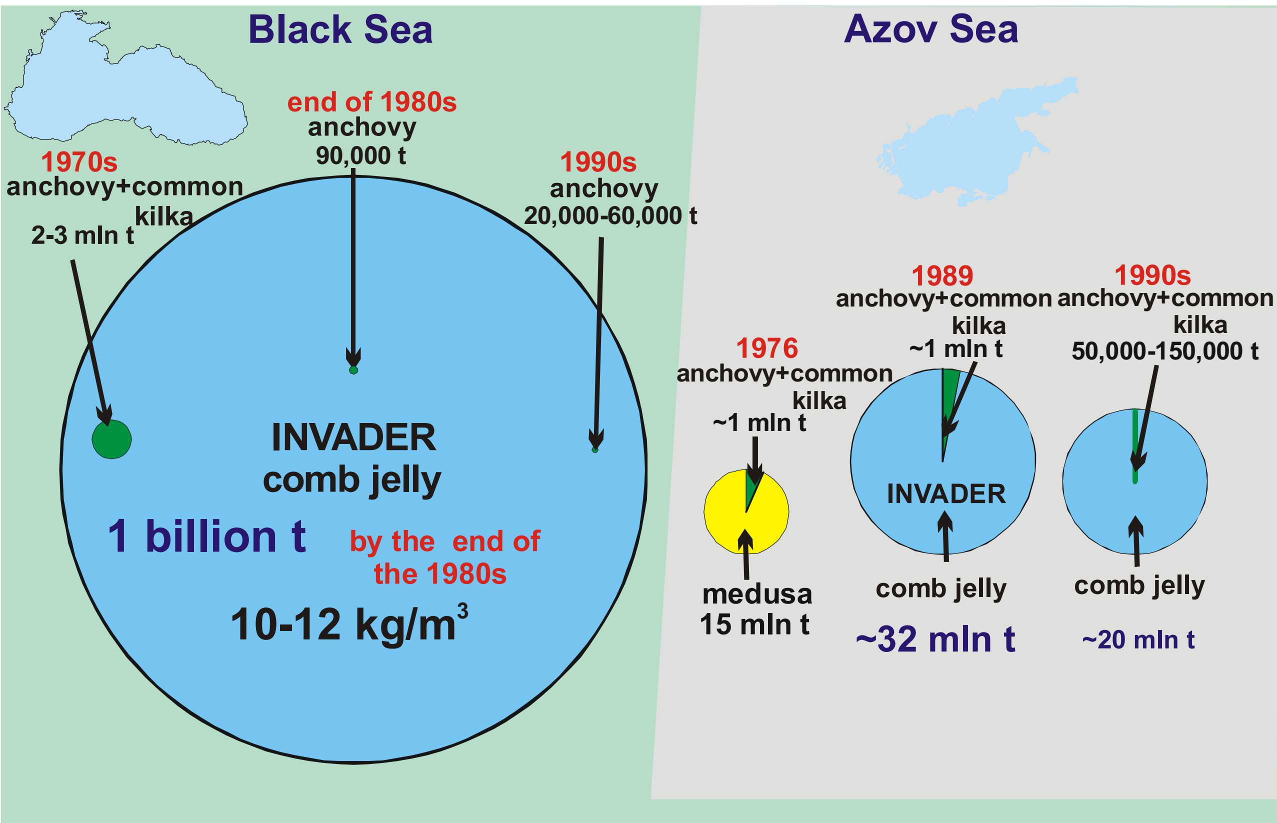


Fig. 73. Biomass ratio of the main competitors for food in the Azov Sea and the Black Sea (by the data of Vinogradov et al. 1989, Shushkina 1991, Volovik et al. 1998, Zaitsev et al.1998)

The growing concern about the future of the ecosystem in the Black Sea and the Azov Sea basin stimulates search for the new effective measures to withstand the impact of undesirable introducers. GESAMP working group elaborated guidelines and possible measures aiming at regulation of the comb jelly populations (GESAMP report 1995). Mechanical, chemical and biological means of control over *Mnemiopsis* abundance are discussed. Biological means seems preferable, as it suggests the introduction into the ecosystem of the basin the species feeding on jelly fishes. *Peprilis triacannthus*, fam. *Stromiatidae*, best matches criteria worked out for introduction. This fish species regulates the abundance of comb jelly in several regions in the North America (Harbison 1993), has good adaptability to the conditions of artificial rearing and high commercial value (Solodovnikov 1997). Such option as introduction of a predator comb jelly of the *Beroe* genus were also considered as they are known to eat out *Mnemiopsis* in other seas.

But taking into consideration all above mentioned, it is highly risky to use new introducers as the balance to *Mnemopsis*. Many specialists, and Yu.P.Zaitsev (1998) in particular, point out that in order to do so a series of measures aiming at restoration of the local fish species populations should be implemented. The efforts should evidently be focused on the restoration of the abundance of the Black Sea scad and mackerel capable to feed on *Mnemiopsis*.

Search for ecologically safe but effective measures of combating exotic species expansion is the most important challenge for natural sciences and fishery. Without solving this problem it will be impossible to maintain the natural reproduction and the artificial rearing of the local valuable fish species.

GENERAL CONCLUSION (ECOSYSTEMATIC PHILOSOPHY)

Geotectonic changes of the Earth's crust during the past geological epochs resulted in establishing of natural bridges, new straits, periodical desiccation of the shelf which promoted to the natural migrations of organisms and evolution of marine and terrestrial ecosystems (**Fig.** 74).

Development of civilization, especially during the past 100 years, contributed considerably to the evolution of the ecosystems (**Fig.** 75). The combination of construction of canals, dams, large scale shipping, settling of exotic species, growth of the artificial mortality of many marine mammals and fish species, chemical contamination by the beginning of the 21st century led to the situation, when ecosystems acquire the features favorable for domination of new fish species with little commercial value and the aboriginal fishes lose the competition.

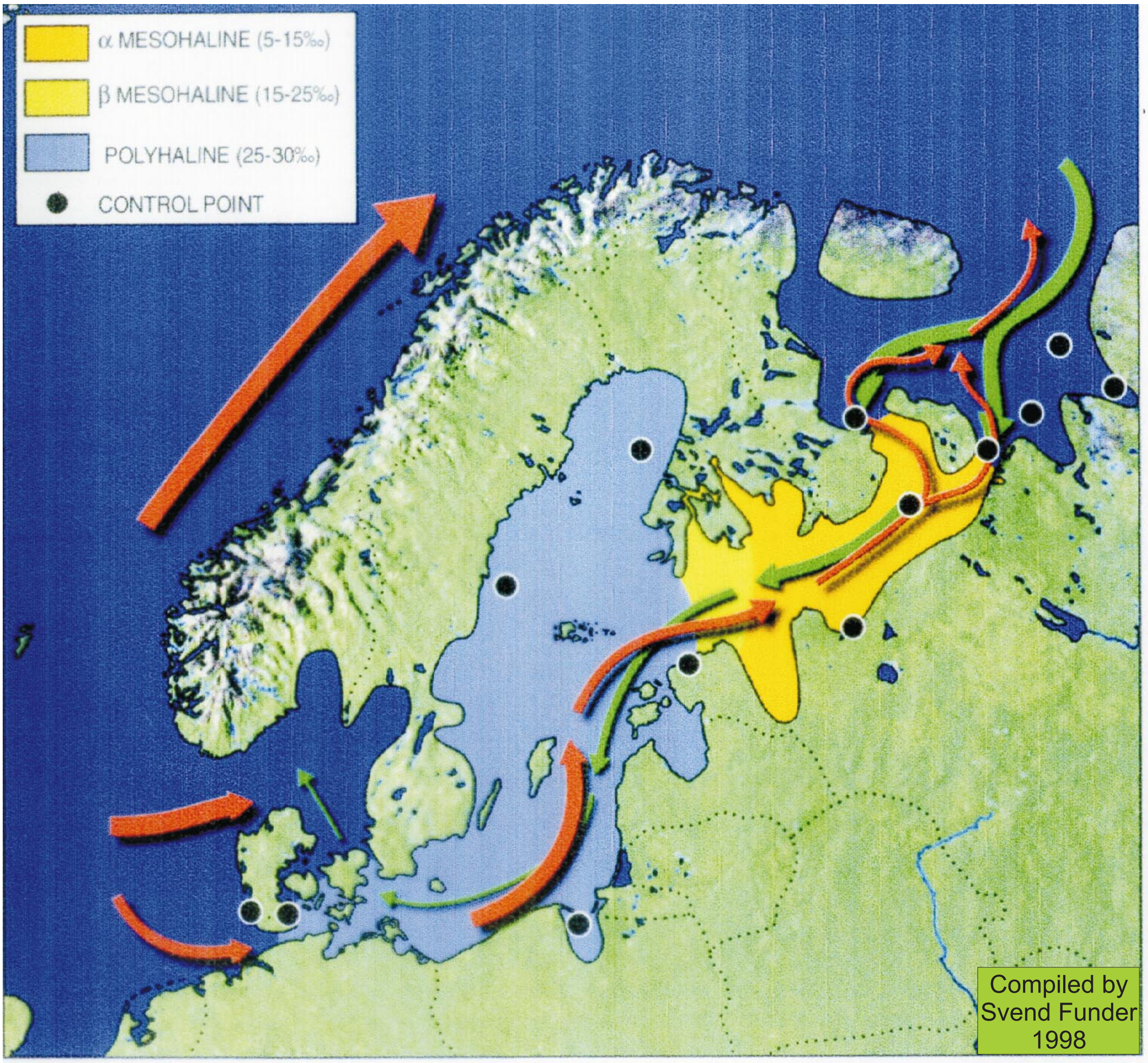


Fig. 74. Example of marine biota settling via land (by Sv. Funder 1998)

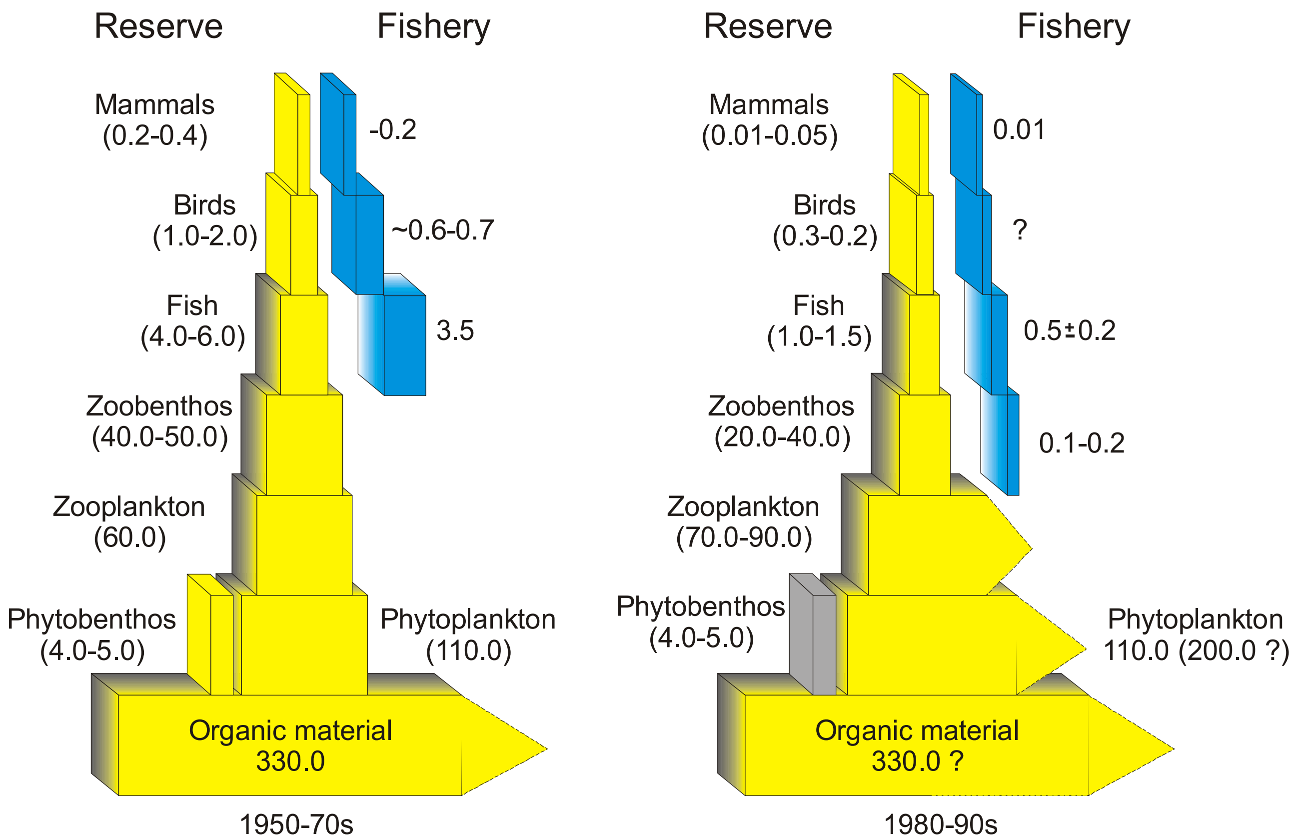


Fig. 75. Pattern of the Barents Sea ecosystem pyramid changes in the 1950-90s (annual production and the fishery stress, million t)

Marine ecosystems preservation is impossible without the agreed position of all the institutions. The fate of the sturgeons in the Azov Sea may serve as a glaring example of the non-coordinated actions of all the ministries and absence of the uniform state policy. In the late 1950s and early 1960s several development programs incompatible with preservation of ecological balance overlapped.

Firstly, the Tsymlyansk hydro power plant construction was finished which cut off the major part of the sturgeon spawning grounds. Secondly, the hydrochemical regime and the contamination level in the waters of the Azov Sea changed because of the river run-off decrease and fulfillment of the program of agricultural use of chemicals. Thirdly, at the same time the intensive extraction of the Azov Sea gobies (in 1957 up to 92,000) with the trawls which practically plowed the ground together with the bottom fauna. As the result, the forage base of the sturgeons was destroyed. It is known, that the main food item of the white sturgeon and the starred sturgeon are the gobies and that of the sturgeon are worms and benthic mollusks. All these upset the natural population of the sturgeon and since the 1980s it is maintained by artificial rearing.

Luckily a large project of construction a dam across Strait of Kerch at the beginning of the 1970s has not been realized. The idea to build a hydro complex was the reaction to inflow of the Black Sea salt water to the Azov Sea in conditions of the fresh water run-off deficit. The consequences might have been similar to the Gulf of Finland situation, which is barred with a dam. Artificial reduction of water exchange with the Baltic Sea increased the accumulation of pollutants, eutrophication and other stagnation phenomena.

The examples of such an attitude towards highly productive water reservoirs are many. The fate of the Aral Sea is the most dramatic.

As far as ecological problems connected with the introduction of the exotic fauna into the European seas (including intentional introduction) are concerned the following should be noted. The total ecosystematic consequences of the given process are negative, mainly due to the mixing of the natural faunas, populations and genetic funds, loss of the natural zoogeographical identity, ousting of the aboriginal ichthyofauna. That is why either habitual for many decades practice of "nature improvement" by introduction or steady restoration of aboriginal fauna should be recognized as a long-term priority.

We adhere to creating conditions for restoration of aboriginal valuable fish species. Any outside intrusion into marine ecosystems, introduction included, must be preceded by biological evaluation and state assessment. The role of studies of institutes of Russian Academy of Sciences in dealing with this problem should become more prominent.

One of the main conclusions of this work is that contemporary changes in populations structure, species composition and general misbalance of the biological processes in marine ecosystems resulted from a combination of numerous direct and indirect factors (**Fig.** 76–78).

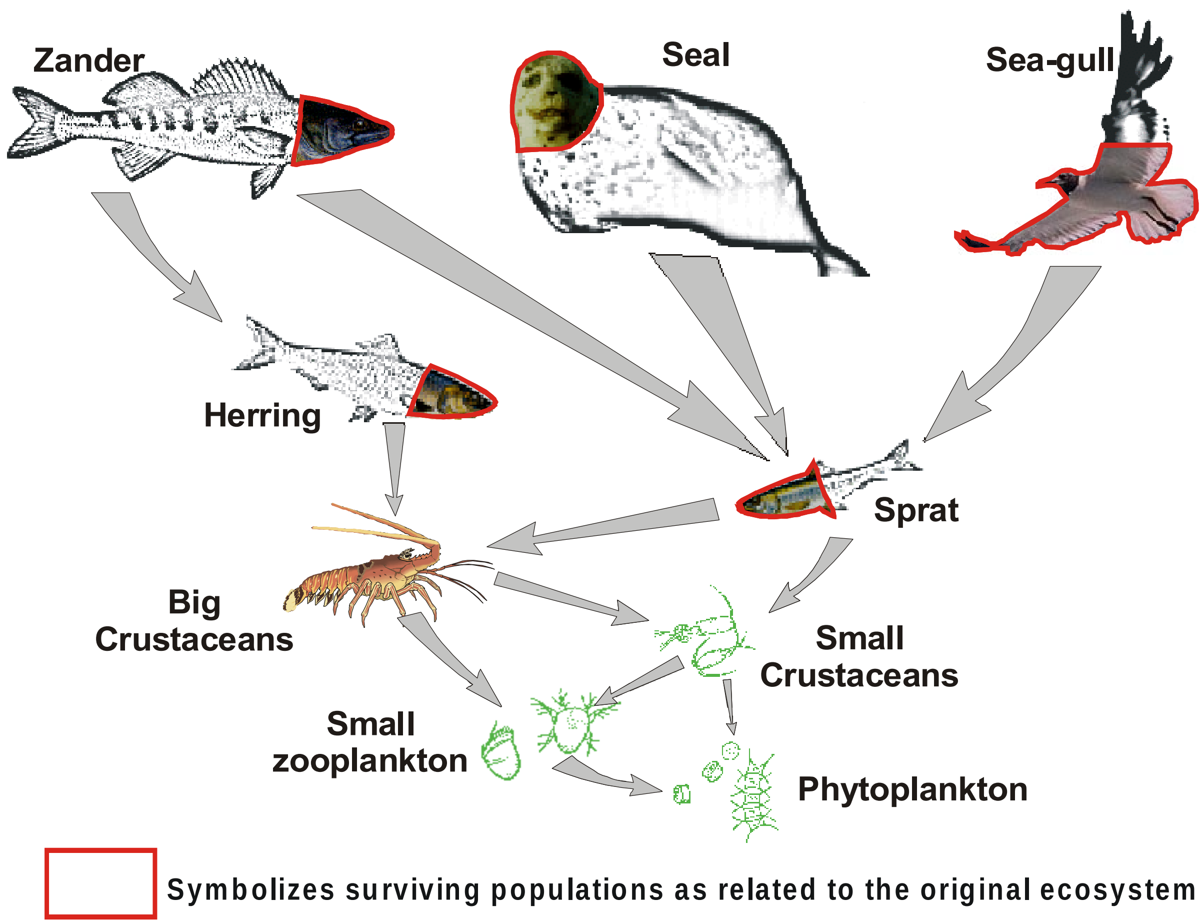


Fig. 76. Current pattern of the food chain in the ecosystem of the pelagic waters of the Caspian Sea (the pattern principles by Zenkevich 1963)

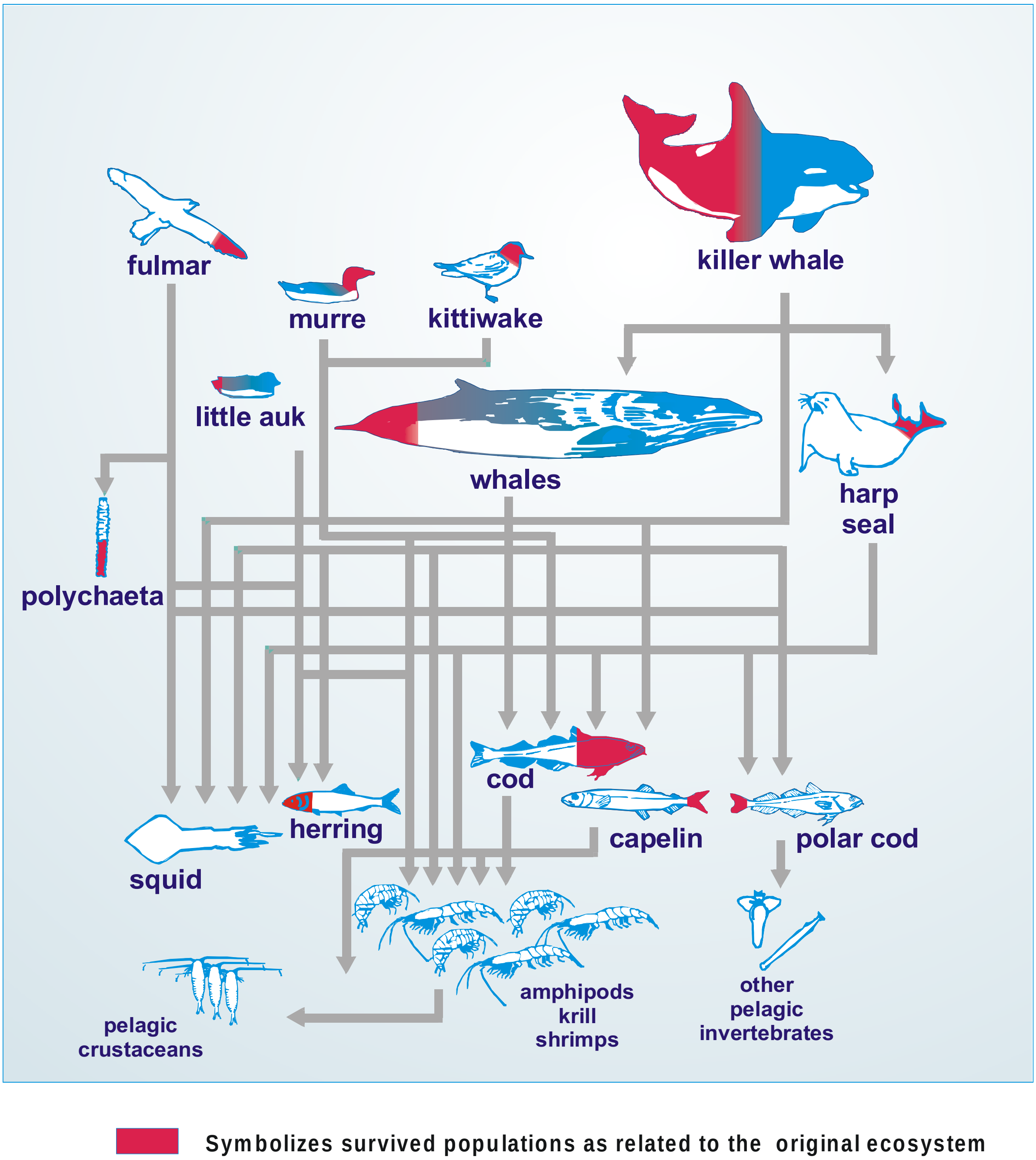


Fig. 77. Disrupted system of natural interrelations in the Barents Sea ecosystem (Atlantic waters) (the pattern principles by The State of the European Arctic 1996)

Mass cannibalism, lowering of the growth rate, fecundity, fatness, eggs size clearly indicate the tendency of decreasing level of natural restoration of practically all main commercial fish species. On the whole, fall of reservoirs' fish productivity predetermined a sharp decrease of abundance of sea animals feeding on fish. Overexploitation caused the reduction of original abundance of commercial fauna from walruses and whales to mollusks.

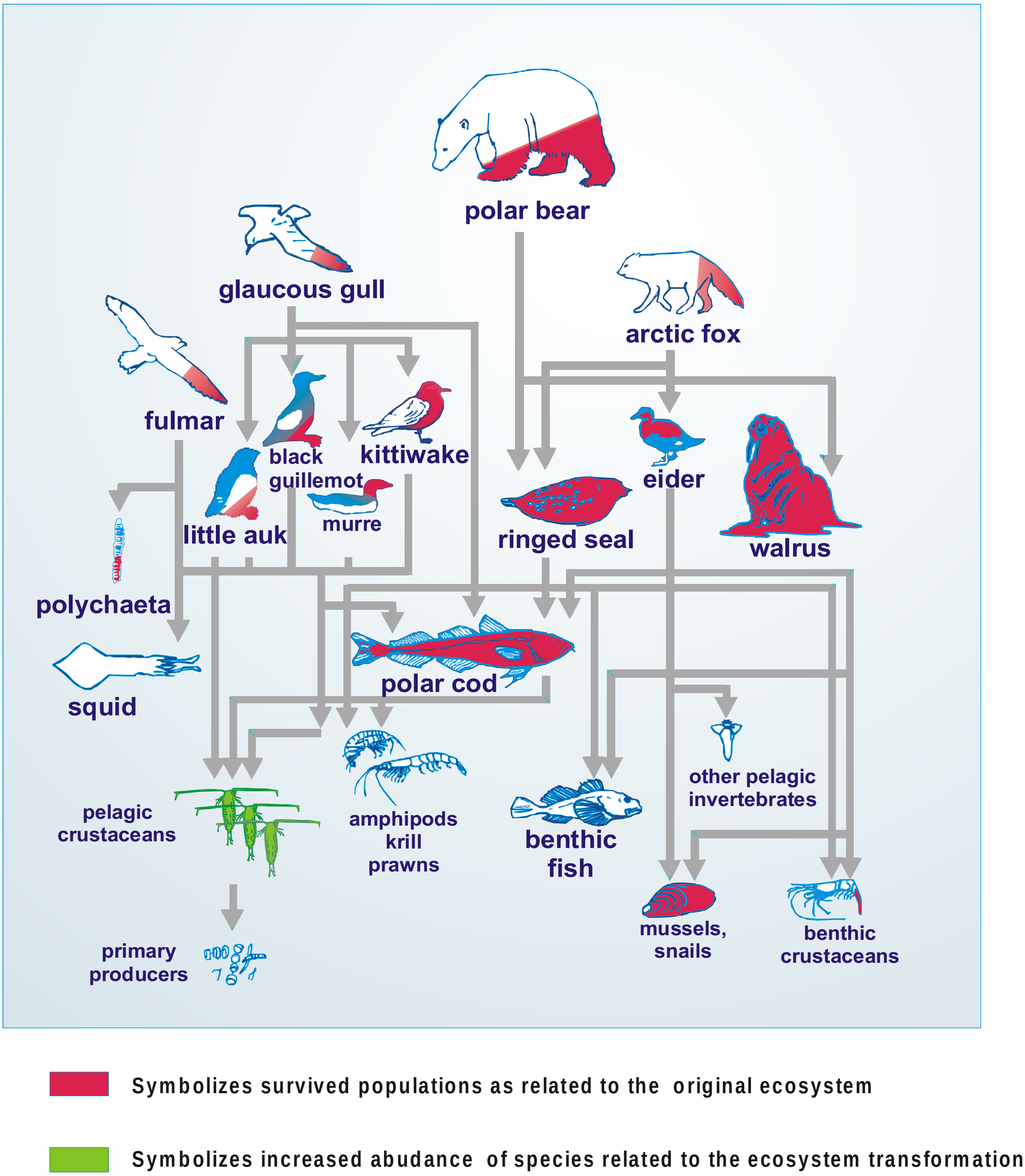


Fig. 78. Disrupted system of natural interrelations in the Barents Sea ecosystem (Arctic waters) (the pattern principles by The State of the European Arctic)

The given analysis allows us to come to the conclusion, that in both the northern and the southern seas the overcatch of the mass pelagic fish species – herring, polar cod, capelin, Black Sea sprat (common kilka) and European anchovy turned out to be the main reason of upsetting of the energy balance and the ecological pyramid. These small shoal fishes are known as the key elements in the marine ecosystem food chains. In fact, almost unbridgeable gap has appeared in marine ecosystems between its inferior (plankton, benthos, algae) and top elements (predator fishes, birds, mammals).

According to the estimations of *PINRO* and *VNIRO* specialists, the total catch of Russian fisheries in the European seas of Russia at the turn of the 21st century will comprise 400,000–600,000 t depending on the mode of exploitation. The Barents Sea share in the amount and diversity of bioresources will remain the biggest.

We cannot but mention the further development of the Barents Sea ecosystem crisis which started in the 1980s. During the last two decades, the population of such Barents Sea species as halibut, wolfish, ocean perch, plaice has not reached ecologically safe indices. The consequences of collapse of populations of such key pelagic fishes as herring and capelin will be surely observed in the next century. Attempts to resume catching of herring and capelin during temporary outbursts of abundance can only aggravate the Barents Sea ecosystem unbalance.

The said bioresources procurement could be economically justified in the 1950–80s when both mariculture and the market were undeveloped. At the same time, long term consequences on the ecosystem level were not as clear as at the turn of the 21st century. Restoration of marine ecosystems calls for setting up limitations on procurement of Arctic cod, common kilka, capelin and other small fishes. This would be good for the state as it will give a chance not to waste valuable commercial fish species completely.

Further use of marine bioresources requires switching from maximum allowable catch assessments of several principal commercial fish species and marine mammals to the principles of ecosystem management.

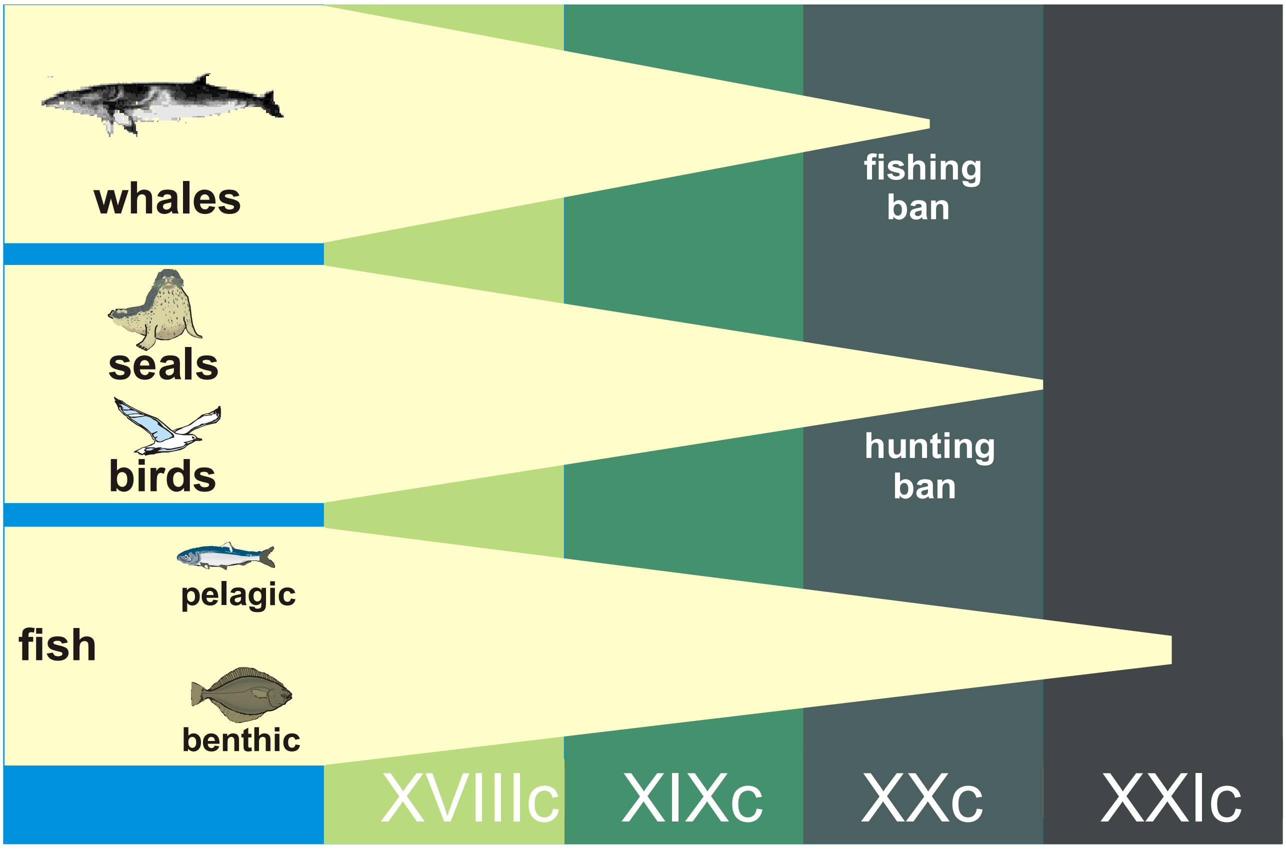


Fig. 79. Dynamics of decrease in commercial fish species abundance in the European seas of Russia

Restoration of the abundance of the mass small-size fish species will provide the conditions for preserving of sea avifauna and especially of such groups of birds as the guillemots (the Alciformes). In the current situation principally new approach to creation of the modern concept of exploitation of water animals is needed. It should be based on really new notions of the role of sea birds and marine mammals taking into consideration their multiple interrelations with the other elements of marine ecosystems. Otherwise the traditional ways of sea birds and marine mammals protection (establishing of nature reserves and protected areas) become pointless.

The modern approach is that chemical contamination is the dominating factor that influences the biosphere. This is true for the terrestrial ecosystems but not for the marine ones. The polluted Azov Sea and practically clean Barents Sea might serve as an illustration. Despite big difference in the levels of contamination, the decrease of commercial species abundance is practically the same (5–10 times). This fact can hardly be disputed. In our opinion, determination of a single contamination factor is not sufficient for explaining of the ongoing changes.

Marine ecosystems susceptibility to the anthropogenic and natural pressure depends on the basin’s dimensions, intensity of the exchange processes with the World Ocean, degree of seawater freshening or salinization, scale of the water reservoirs productivity and other factors. Development of quantitative criteria and thresholds of the marine ecosystems stability needs special investigations so that to prevent continuous decrease of bioresources abundance in the European seas of Russia (**Fig.** 79).

Thus, if the above mentioned seas be positioned on a virtual scale of anthropogenic transformations, then the ecosystems of the Barents and the White Seas will take position in the least affected sector. The Baltic, Black and Caspian seas biota are affected to a greater extent. The situation in the Azov Sea, like that in the Aral Sea, which reflects all the negative aspects of human activity, may be defined as an ecological catastrophe of the end of the 20th century.

Solving this national level problem calls for placing it among the highest priorities of fundamental scientific research and the programs of the economic development of the country.

Everything mentioned above is only a part of the problems which, in our opinion, deserve special attention of the academic and applied science, legislative and executive bodies.

CONCLUSION

Evolution of the marine biota on the population and the ecosystem levels is determined by the natural course of natural processes. Evidently, the climatic changes are the most important factor. The excessive pressure of whaling and fisheries, which procure whales, seals, fish and other bioresources (mollusks, algae, etc.), should be regarded as the major anthropogenic factors which influence marine ecosystems in the 20th century. The negative impact of hunting sea animals and large scale fishing, known as overcatch, is internationally recognized by both scientists and specialists.

Any disturbance of the ecological balance in general and high fishing mortality, degraded spawning grounds, deficiency of forage in particular, hinder the rate of natural reproduction. At the moment, all valuable fish species of the northern and the southern seas are more or less affected by this process. This triggered accelerated maturation and growth rate, decrease of the maximum and the mean size of individuals in the populations, rejuvenation of the populations of the majority of commercial species.

By the end of the 20th century, the gray and the ringed seal, the Atlantic walrus and some other polar pinnipeds are being referred to as rare and specially protected. Bad living conditions and absence of proper protection In the southern seas put the marine mammals to the verge of extinction. The fate of colonial and marine birds species is very much the same. They play an especially important role in the organic matter cycle including a trophoparasitary chain.

The most vulnerable sea fish are the short-lived pelagic species. Natural cycles are characteristic of their reproduction. When a poor year and heavy fishery stress coincide in time a population collapses.

The sturgeons are top commercial species in the southern seas. In the north, the Atlantic salmon plays a similar role. The sturgeons cause serious concern, because the irreversible processes take place in the mechanism of their reproduction and this leads to fading of the process of the natural reproduction of the population.

The given analysis demonstrates quite convincingly the general tendency of steady decrease (with rare exceptions) of abundance and catches of practically all commercial fish species at the end of the 20th century. The natural reaction to decrease of reproductive capacities of the given ecosystems was the introduction of the commercial fauna species from the water reservoirs of other continents in the 1950–80s.

Transformation of marine biota species composition as the result of invasion of exotic species, introduction and other anthropogenic factors disrupted the ecosystems. Many exotic species, being ecologically flexible and having high rate of reproduction, develop into numerous populations in new reservoires and deeply affect species and forage composition of ecosystems. That is why dubious biological consequences resulting from natural and artificial replacement of vanishing or feeble elements of marine ecosystems need special consideration.

The half a million population of the Kamchatka crab in the coastal zone of the Barents Sea successfully competes with the aboriginal fauna for the same food resources. The Caspian crawfish Cercopagis settled down in the Gulf of Finland and spreads in the Baltic Sea gradually forcing the Baltic anchovy and sprat out of their niche. Striped mullet and stone moroco in the Azov Sea gradually supersedes the valuable local fish species in their ecological niches. The outburst of the abundance of the comb jelly, which was brought from the East American waters in the 1980–90s, turned out a disaster for the Black Sea and the Azov Sea basin.

These permanent processes affect all trophic levels from whales, dolphins, birds to many plankton species. Introduction makes some sense in the marine basins with a degraded fishery sector of the ecosystem. But from the biological point of view introduction of new species is not always justified.

Any forms of uncontrolled introduction of exotic biota into natural environments of sea organisms should be stopped. This concerns e.g. export of exotic species with ballast waters of vessels or in the course of introduction of new fish species. Nowadays It is highly hazardous to use new introducers as the balance to exotic species. In order to do so the complex of measures aiming at restoration of the local fish species populations should be realized. The efforts should preferably be focused on the restoration of the abundance of the Black Sea scad and mackerel, which are capable to feed on e.g. *Mnemiopsis* and similar animals.

Search for the ecologically safe and effective methods of dealing with the expansion of the exotic species of fauna is the most important task of natural science and practical workers. Without solving this problem it will be next to impossible to support natural reproduction and artificial rearing of local valuable fish species.

It is expedient to concentrate efforts on the compensating role of aquaculture. The southern basins (the Azov Sea, the North Caspian Sea) may concentration the full cycle artificial rearing of valuable fish species from fish eggs to ready made product (sea as a “big cage”). Rearing of the sturgeon is the most promising branch. Artificial breeding of young fish with subsequent release into natural environment is possible in less favorable conditions of the Barents Sea. Programs of mariculture development in the seas of Russia should also be elaborated with consideration of interrelations in ecosystems, so that not to upset them. The emphasis should be laid upon restoration of the aboriginal fauna species. The task of applied and fundamental science is to broaden the spectrum of studies of marine animals genetics, selection and adaptability to changing environment.

A series of other commercial practices is known to have negative impact on benthic communities. The major factors are trawling of fish and invertebrates, mass transport of ground during dredging of access canals in shallow waters and chemical contamination in general. Undifferentiated approach to the standardization of the anthropogenic pressure on the marine ecosystems may lead either to the discrediting of useful ideas and methods or countless economic losses.

Thus, at this stage, the objectives of marine bioresources preservation may be determined as follows:

- Establishment of the state program of biological research of the European seas of Russia (the structure and the functioning of the marine ecosystems);
- Restoration of the state ecological monitoring of the marine environment and biota;
- Providing of the effective control of catches and fishery management, restoration of the fishery statistics;
- Introduction of the state control over adaptation and introduction of the new items;
- Development of the artificial restoration of fishes, the pasture rearing of fishes and marine culture.

With reference to this problems we should say that at the moment the attention to the fundamental problems of marine biology falls behind the modern requirements. For instance, the biological section of the Federal Program “World Ocean” traditionally focuses on the resources and the role of the relevant governmental agency, while the role allotted to the academic science is not defined precisely.

Thus, development of civilization against the background of global natural changes resulted in decrease of key species abundance and change of their ratio by the beginning of the 21st century. It was followed by modifications of the general structure and cycle of ecosystems. These changes have a uniform outcome, though causes are different. The detected changes are hardly the result of a single factor, e.g. pollution.

Anthropogenic pressure, consequently, causes decrease of production of the ultimate element of the trophic chain, including valuable fish species, birds and marine mammals. The reaction of the ecosystem to anthropogenic pressure is lowering of the energetic balance level because of the changes in energy fluxes in trophic chains and disruption of the top elements of the pyramid. Unfortunately, all attempts to restore original state of the ecosystem and to recover abundance of traditional objects of fishery do not reach the desired objectives.

The strategy of the marine nature protection should be based on progressive development. and introduction of ecologically pure technologies in all spheres of human activities, which will ensure a breakthrough reduction of harmful substances input into estuarine and marine ecosystems. Our goal is to join our efforts for ecosystem forecasting, in order to chose the best ways of marine bioresources exploitation which will be our input into development of terrestrial and marine economic practices in Russia in the 21st century.

In conclusion we would like to point out, that this extremely complicated question has not been exhausted. We are sure that Russia must not, at least, waste its biological marine resources. Countries where the diet comprises a lot of sea food have the longest life expectancy. That is why the role of fundamental biological research in elaboration of theory of functioning of marine ecosystems should match importance and extent of the given task.

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Zenkevich, L.A., Zevina, V.S. 1969. Fauna i flora [Fauna and flora.] In Kaspijskoe more. [The Caspian Sea.] M., p. 229–256. (In Russian)

Zhuravleva, N.G., Zenxzerov, V.S. 1998. Ekologo-morfologicheskie osnovy marikul'tury ryb v Zapoljar'e. [Ecologic- morphological grounds of the marine culture of fishes beyond the Polar Circle.] Apatity, 374 p. (In Russian)

Appendix

MONOGRAPHS AND COLLECTIONS OF PAPERS ISSUED BY MURMANSK MARINE BIOLOGICAL INSTITUTE OF KOLA SCIENTIFIC CENTER RUSSIAN ACADEMY OF SCIENCES IN 1990–1998

1990

Denisenko, N. V. 1990. Raspredelenie i ekologija mshanok Barenceva morja [Distribution and ecology of pearlworts of the Barents Sea.] Apatity, 158 p. (In Russian)

Matishov, G. G., Pavlova, L. G. 1990. Obschaja ekologija i paleogeografija poljarnyh okeanov [General ecology and paleography of polar oceans.] L., 224 p. (In Russian)

Morfologija i ekologija parazitov morskih zhivotnyh. 1990. [Morphology and ecology of the parasites of marine animals]. In Otv. red. A. A. Dobrovol'skij [Edited by A.A. Dobrovolsky.] Apatity, 115 p. (In Russian)

Savinova, T. N. 1990. Himicheskoe zagrjaznenie severnyh morej. [Chemical contamination of the northern seas.] Apatity, 146 p. (In Russian)

Sensornaja fiziologija morskih ryb (metodicheskie aspekty). Otv. red. N. Akoev. [Sensory physiology of marine fishes (methodical aspects). Edited by N. Akoev]. Apatity, 128 p. (In Russian)

Strukturno-funkcional'naja organizacija ekosistem Barenceva morja. 1990. Otv. red. G. G. Matishov. AN SSSR, Kol. nauch. centr, Mur. mor. biol. in-t. [VINITI 05.10.90, [1] 5272-V90. Dep. in All- Union Inst .Tech. Inf. [Structural- functional organization of the Barents Sea ecosystems. Edited by G .G Matishov AS USSR, Kola scient. Center Murm. Biol. Inst.] Apatity, 246 p. (In Russian)

Teplinskaja, N. G. 1990. Processy bakterial'noj produkcii i destrukcii orga-nicheskogo veschestva v severnyh morjah. [Processes of bacterial production and destruction of the organic matter in the northern seas.] Apatity, 106 p. (In Russian)

Chernickij, A. G., Loenko, A. A. 1990. Biologija zavodskoj molodi semgi posle vypuska v reku. [Biology of the fish farms' young of salmon after the release into the river.] Apatity, 118 p. (In Russian)

Ekologija i biologicheskaja produktivnostj Barenceva morja/ 1990. Otv. red. G. G. Matishov. [Ecology and biological productivity of the Barents Sea. Edited by G. G .Matishov.] M., 119 p. (In Russian)

1991

Voskobojnikov, G. M., Kamnev, A. N. 1991. Morfofunkcional'nye izmenenija hloroplastov v ontogeneze vodoroslej. [Morpho-functional changes of chloroplasts in the ontogenesis of algae.] SPb., 96 p. (In Russian)

Produkcionno-destrukcionnye processy pelagiali pribrezh'ja Barenceva morja. 1991. Pod red. G. G. Matishova. [Production- destruction processes of the pelagial of the Barents Sea. Edited by G.G. Matishov.] Apatity, 108 p. (In Russian)

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1992

Matishov, G. G. Antropogennaja destrukcija ekosistem Barenceva i Nor-vezhskogo morej. [Anthropogenic destruction of the ecosystems of the Barents and the Norwegian Seas.] Apatity, 112 p. (In Russian)

Primenenie metodov informatiki i statistiki v gidrobiologicheskih is-sledovanijah Barenceva morja. 1992. Pod red. G. G. Matishova. [Application of the statistics and computation methods in the marine biology investigations of the Barents Sea. Edited by G. G. Matishov.] Apatity, 128 p. (In Russian)

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Hranenie i obrabotka eksperimental'nyh dannyh. Matematicheskoe modelirovanie. 1992. [Preserving and processing of the experimental data. Mathematical modeling.] Apatity, 89 p. (In Russian)

Phytoplankton of the Barents Sea. 1992. Ed. G. G. Matishov. Apatity, 118 p.

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Adrov, N. M. 1993. Transformacija vodnyh mass sistemy Gol'fstrima. [Transformation of the water masses of the Gulf Stream system.] Apatity, 171 p. (In Russian).

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Matishov, G. G., Sochnev, O. Ja., Chernook ,V. I. 1993. Distancionnyj ekogicheskij monitoring Barenceva morja. [Remote sensing ecological monitoring of the Barents Sea.] Apatity, 125 p. (In Russian)

Orlova, E. L., Matishov, G. G. 1993. Strukturno-funkcional'naja rolj treski v ekosisteme Barenceva morja. [Structural- morphological role of cod in the ecosystem of the Barents Sea.] Apatity, 163 p. (In Russian)

Sensornaja morfofiziologija morskih ryb. (Materialy mezhdunarodnogo seminara). 1993. Otv. red.: P. S. Enger, I. A. Shparkovskij. [Sensory morpho-physiology of the marine fishes. (Materials of the International Seminar). Edited by P. S. Enger, I. A Shparkovsky.] Apatity, 112 p. (In Russian)

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